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MODULAR DEVELOPMENT PHASE MONITORING REPORT THREE

VOLUME 1 OF 3 – TEXT

December 1977 – November 1978

Year-End Report

Gulf Oil Corporation / Standard Oil Company (Indiana)
A General Partnership
9725 East Hampden Avenue, Denver, Colorado 80231

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RIO BLANCO OIL SHALE COMPANY
MODULAR DEVELOPMENT PHASE
MONITORING REPORT 3

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December 1977 - November 1978

YEAR-END REPORT

Prepared by:
RIO BLANCO OIL SHALE COMPANY
DENVER, COLORADO

March 31, 1979

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SECTION 1
INTRODUCTION

Since its inception in 1974, the RBOSC has been conducting extensive environmental data collection programs. Between October 1974 and September 1976, two years of baseline data were gathered. From September 1976 through August 1977, interim environmental data were collected during the period in which RBOSC had suspended most tract development activities. In September 1977, RBOSC initiated their Modular Development Phase (MDP) Environmental Monitoring Program. The first report of MDP environmental activities (September - November 1977) was published in February 1978; the second report (December 1977 - May 1978) was published in September 1978. This is third report describing MDP environmental activities. This report, RBOSC MDP Monitoring Report 3, presents data collected during the summer (June, July, August) and fall (September, October, November) seasons, discusses the data collected from December 1977 through November 1978, and compares MDP data with baseline and interim data.

The RBOSC MDP Environmental Monitoring Program provides air quality, meteorology, terrestrial ecology, aquatic ecology, and hydrology data. Monitoring program designs were based on analysis of baseline and interim studies data, an assessment of probable developmental impacts, and recommendations from the Area Oil Shale Office (AOSO). The MDP monitoring program was conducted according to the document "RBOSC Modular Development Phase Environmental Monitoring Program Scope of Work" dated March 17, 1978. This scope of work reflects the environmental monitoring philosophy set forth in RBOSC's Revised Detailed Development Plan (RDDP).

Air quality, meteorology, terrestrial ecology, and aquatic ecology studies described herein were conducted by NUS Corporation. Hydrology studies were carried out by Wright Water Engineers, and the United States Geological Survey (USGS). Dames and Moore collected the visibility data, and Morrison-Knudsen, Inc. collected the noise data.

Volume 1 of the RBOSC MDP Monitoring Report 3 contains six sections as follows:

Section 1 - Introduction
Section 2 - Atmospheric Studies
Section 3 - Terrestrial Studies
Section 4 - Aquatic Studies
Section 5 - Hydrology Studies
Section 6 - Summary

Other volumes contain data appendices as listed below:

2-1 Air Quality Data
2-2 Climatological Data
2-5 Visibility Data
3-2 Vegetation Data
3-3 Fauna Data
4-2 Aquatic Studies Data
4-3 Periphyton Data
4-4 Benthos Data
4-5 Aquatic Biota Statistical Calculations
5-1 Surface Water Data
5-2 Ground Water Data
5-3 MDP Pump Test Data

In addition to the hard copy data presented in the appendices, data are also presented on 800 bpi magnetic tapes.

SECTION 2

ATMOSPHERIC STUDIES

The Tract C-a atmospheric studies program consists of two elements - (1) measurements of total suspended particulate matter and certain chemical compounds, and (2) measurements of selected meteorological parameters. The monitoring locations were originally established to measure the ambient air quality generally upwind and somewhat removed from the expected tract development, and at points where tract developments might have an effect on the air quality. Simultaneous meteorological measurements were made to allow evaluations of air quality changes and for prediction of the dispersion of emissions from tract development.

Air quality and meteorological data have been obtained from monitoring instruments located on or near Tract C-a since February 1975. The first two years of data collection make up the baseline data set, composed of data obtained at four locations around the tract. Following the baseline period, an interim data acquisition program was established to cover an interval during which the tract development lease conditions were modified and partially suspended. During the interim period (February through August 1977), a single air quality and meteorological monitoring station was operated to maintain data continuity.

The current program is part of the Modular Development Phase (MDP). The level of activity on the tract, principally construction work, has increased significantly during the MDP period. The monitoring program has also been increased in order to measure possible effects on the ambient air quality. Two of the sites that had been deactivated for the interim period were refitted with meteorological instrumentation and put back online during the MDP first quarter. In addition, one of the reactivated meteorological sites is gradually being refitted with a set of air quality instrumentation. This will be completed by June 1979.

2.1 AIR QUALITY

National Ambient Air Quality Standards (NAAQS) have been adopted to ensure safe concentrations of certain pollutants in the ambient air. Air quality monitoring has been conducted on and near Tract C-a to establish the existing level of these pollutants before and during tract development. Tract development activities are expected to result in the emission of certain gases into the ambient air that have the potential for adversely affecting air quality.

An ambient air monitoring network (Figure 2-1) was established for measuring gaseous pollutants at the outset of the MDP monitoring period. Site 1 is located just west of the tract boundary. A second air quality monitoring station located just east of the tract boundary, identified as Site 3, was brought online during the first quarter of the MDP program. Both sites were also operational during the baseline period. In contrast to Site 1, which generally measures background ambient air quality, Site 3 is located in a broad gulch that may experience some air quality changes due to dispersion under downvalley flow from the main development area in the center of the tract. The monitoring instruments at each site are housed in an environmentally controlled shelter and draw a sample of the ambient air from a common glass manifold which has an intake 4 m above the ground. Each monitoring instrument is connected to a strip chart recorder which continuously records the instrument output signal. In addition, an automatic data acquisition system scans each parameter being measured once every three minutes and computes a running 15-minute average. The current average value is recorded on magnetic tape at the end of each quarter hour. Hourly averages are automatically computed from the 15-minute averages when the data are reduced. The hourly average value of a parameter is centered on the hour (i.e., the data point computed at 0200 hours is the average of data obtained between 0130 and 0230). Air quality data taken during the fourth and fifth quarters of the MDP program are presented in Appendices 2-1.1 (gaseous constituents) and 2-1.2 (total suspended particulates). As part of the year-end report, an extensive analysis has been carried out on the data obtained during the most recent four quarters of the MDP program (December 1977-November 1978, hereafter referred to as the current year). Comparisons have been made with the results from the baseline

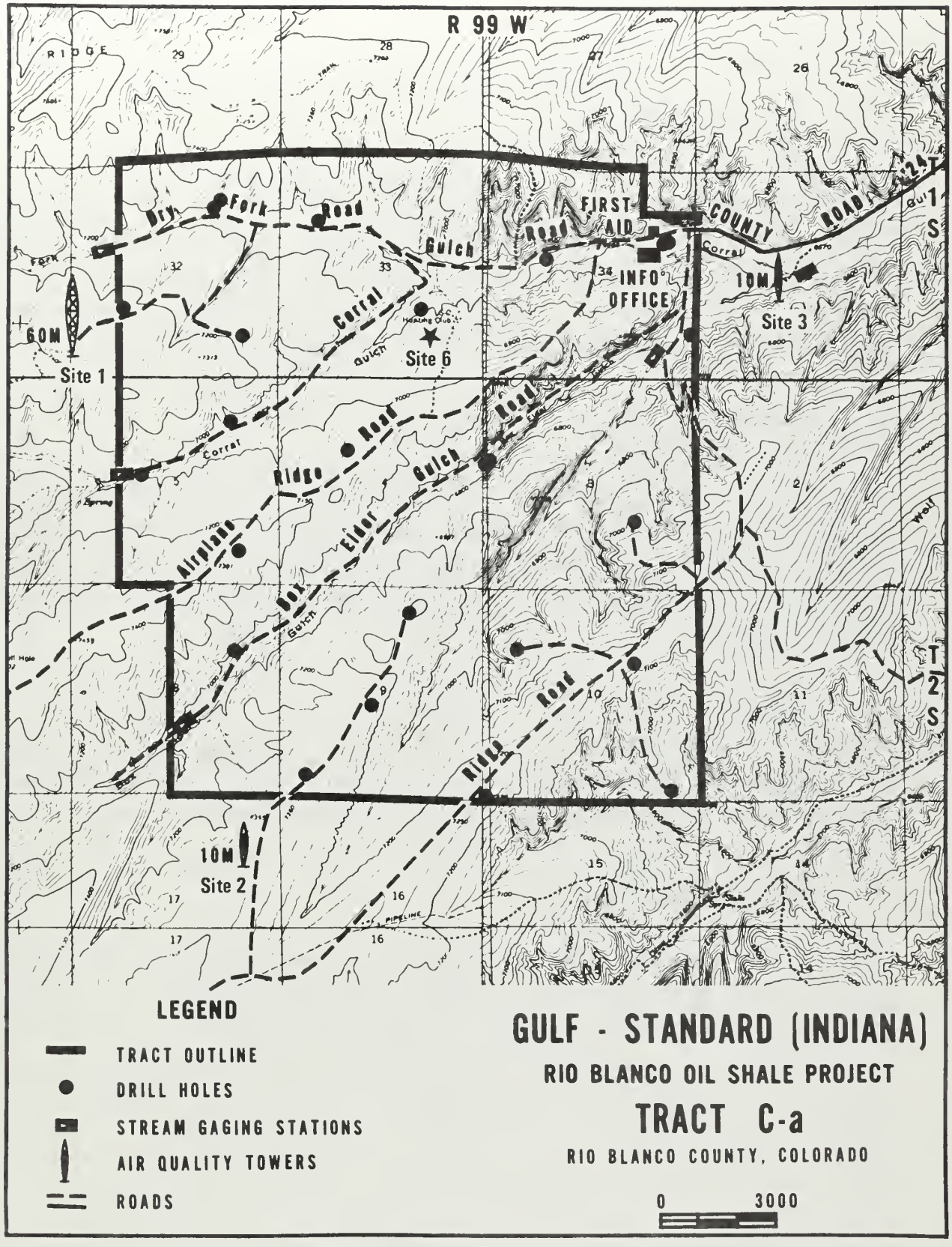
R 99 W
Dry Fork
Road
Gulch
FIRST AID
INFO OFFICE
COUNTY ROAD
Corral
Site 3
Site 6
Site 1
Ridge
Road
Elder Gulch
Airplane
Box Gulch
Site 2
PIPELINE
T 1 S
T 2 S
LEGEND
TRACT OUTLINE
DRILL HOLES
STREAM GAGING STATIONS
AIR QUALITY TOWERS
ROADS
GULF - STANDARD (INDIANA)
RIO BLANCO OIL SHALE PROJECT
TRACT C-a
RIO BLANCO COUNTY, COLORADO
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Figure 2-1.

period (February 1975-January 1977), obtained from the Final Environmental Baseline Report (RBOSP 1977).

A. Sulfur Dixoide

Sulfur dioxide is produced principally by the combustion of sulfur-bearing fossil fuels. At the present time the amount of combustion that takes place in the tract region is very low and it is to be expected that there would be little sulfur dioxide in the ambient air. However, with further tract development some fuel combustion will be required and sulfur dioxide emissions may increase.

1. Objectives

The objective of monitoring for sulfur dioxide is to establish the ambient air concentration prior to and during tract development. The existing sulfur dioxide levels and their associated environmental effects can be compared to future environmental changes that may be related to any increase in the concentration of sulfur dioxide.

2. Methods

The methods followed for collection of sulfur dioxide data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

Hourly average concentrations recorded were between 0.01 and 0.03 ppm at Site 1 and between 0.01 and 0.11 ppm at Site 3, with most of the values at both sites less than the reliable threshold of detection (0.02 ppm). If the recorded concentration of any pollutant was below the reliable threshold of detection, a number equal to one-half of the threshold value was substituted for the data point (adopted from the EPA Quality Assurance Handbook, Air Pollution Measurement, Volume I). Annual mean concentrations at both sites for the current MDP period (Table 2-1) are below the reliable threshold of detection and are therefore set at 0.01 ppm. Mean concentrations during the baseline period were also below the reliable threshold of detection.

TABLE 2-1. ANNUAL SUMMARY OF AIR QUALITY PARAMETERS (DECEMBER 1977 THROUGH NOVEMBER 1978), RBOSC

Parameter	Units	Minimum[1]	Maximum[1]	Arithmetic Mean
		Site 1		
O_3	ppm	0.017	0.088	0.057
CO	ppm	0.5	0.5	0.5
NO	ppm	0.005	0.016	0.006
NO_x	ppm	0.005	0.023	0.006
H_2S	ppm	0.01	0.04	0.01
SO_2	ppm	0.01	0.03	0.01
TSP	$\mu g/m^3$	1.3[4]	58.6[4]	13.6[2]
		Site 2		
TSP	$\mu g/m^3$	1.2[4]	60.2[4]	12.9[2]
		Site 3		
O_3	ppm	0.004	0.072	0.038
H_2S	ppm	0.01	0.55	0.01
SO_2	ppm	0.01	0.11	0.01
TSP	$\mu g/m^3$	1.3[4]	160.[4]	26.3[2]
		Site 6		
TSP[3]	$\mu g/m$[3]	6.7[4]	1805.[4]	95.0[2]

(1) Hourly average
(2) Geometric mean
(3) Based on 10 1/2 months of data
(4) 24-hour averages

B. Hydrogen Sulfide

Hydrogen sulfide in the ambient air is generally the result of emissions from the decay of sulfur-containing organic materials, release from underground oil, gas or water deposits, or emissions as a result of volcanic action. Some low concentrations of hydrogen sulfide might be recorded due to surface pumping of underground water on the tract during the MDP period. There are no air quality standards for ambient air concentrations of hydrogen sulfide in the tract area. However, the gas is toxic, and at low concentrations represents a nuisance because of its odor.

1. Objectives

The objective of monitoring hydrogen sulfide in the ambient air on the tract is to establish the background value. Tract development, which will involve recovery of sulfur-bearing organics, may release hydrogen sulfide into the ambient air. Concentrations of this constituent in the future may be compared to pre-development conditions to assess environmental impacts.

2. Methods

The methods followed for collection of hydrogen sulfide data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

Hydrogen sulfide hourly average concentrations recorded at Site 1 were between 0.01 and 0.04 ppm and at Site 3 were between 0.01 and 0.55 ppm. The annual means at both Site 1 and Site 3 for the current year were 0.01 ppm (Table 2-1) which are below the reliable threshold for hydrogen sulfide. The annual means at both sites during each of the baseline years were also below the reliable threshold of detection. Although there appears to be a significant increase in the maximum value recorded at Site 3 from the baseline period, only a few values were recorded above 0.03 ppm. All hydrogen sulfide concentrations at Site 3 recorded above the instrument threshold occurred at night. These elevated concentrations

are apparently caused by the surface discharge of underground water which contains reduced sulfur compounds during the stable atmospheric conditions which prevail at night. Site 3 is located near the creek into which the underground water is pumped.

C. Nitrogen Oxides

Nitrogen oxides (NO_x) generally are produced by high temperature combustion which fixes atmospheric nitrogen. Nitric oxide (NO) is produced chiefly by internal combustion engines. In the tract area there are only small amounts of automotive exhaust or combustion that would result in the generation of nitrogen oxides, and it is to be expected that no significant concentration of these constituents would be found.

1. Objectives

Nitrogen oxides are monitored to establish the existing natural background levels prior to major tract development and operation. Tract operations will involve substantial combustion with the generation of nitrogen oxides. Nitric oxide in the presence of sunlight and hydrocarbons may be a mechanism for smog production. These data may prove useful in correlating future visibility changes with pollutant concentration.

2. Methods

The methods followed for collection of nitrogen oxides data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

The highest hourly average concentrations for nitrogen oxides and nitric oxide were 0.023 and 0.016 ppm, respectively. The arithmetic means for the period for nitrogen oxides and nitric oxide during both baseline years and the current year are below the reliable threshold of detection of 0.01 ppm.

D. Carbon Monoxide

Carbon monoxide results from the incomplete oxidation of carbon during combustion.

1. Objectives

Carbon monoxide is monitored to establish the ambient air concentration of this constituent prior to and during tract development activities. Vehicular use and fuel combustion during tract development may result in the emission of carbon monoxide in the tract area.

2. Methods

The methods followed for collection of carbon monoxide data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

No measurements of carbon monoxide were reported above the reliable threshold of the instrument. Much of the time the output of the instrument was above the threshold, but this was due to the detector, which produces a mean output signal with predominantly positive noise in the absence of a sample. This was confirmed by comparing the weekly zero checks with the ambient readings of the instrument. In all cases, there was no significant difference between the instrument zero and the ambient measurement. Consequently, no carbon monoxide values above the threshold of the instrument are reported in the data set. The mean carbon monoxide concentrations during the baseline period at both sites were also below the reliable threshold of detection of 1.0 ppm.

E. Hydrocarbons

Hydrocarbons in the atmosphere may originate from a variety of natural and anthopogenic sources. The non-methane fraction may be important on the tract as precursors in the photochemical production of ozone. However, state of the art

instrumentation does not produce reliable data. As a result, the Area Oil Shale Supervisor has waived the requirement for reporting hydrocarbon data (after February 7, 1978), until improvements in the instrumentation are made.

F. Ozone

Ozone concentration is taken as a measure of total oxidants in the ambient air. In urban areas ozone is thought to result mainly from the interaction of nitrogen oxides and sunlight in a complex photochemical reaction initiated by automobile exhaust emissions. A national ambient air quality standard has been established for the concentration of total oxidants in the ambient air. Ozone is a powerful oxidizer and can damage vegetation and materials as well as produce deleterious health effects in man and animals.

1. Objectives

Ozone monitoring is conducted to establish the ambient air concentration of this constituent prior to and during tract development and operation. The potential emissions of nitrogen oxides coupled with hydrocarbons and strong sunlight may produce photochemical reactions in the future in the tract area.

2. Methods

The methods followed for collection of ozone data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

The range of ozone concentrations for the current year was 0.017 to 0.088 ppm at Site 1 and 0.004 to 0.072 ppm at Site 3. The Site 1 mean ozone concentration of 0.057 ppm (Table 2-1) during this data period contrasts with mean concentrations of 0.033 and 0.035 ppm found at Site 1 during the two baseline years.

Better agreement was found with the Site 3 mean ozone concentrations: 0.038 ppm during the current year, and 0.030 and 0.032 ppm during the two baseline years.

The increase in the mean ozone concentration at Site 1 from the baseline period is considered to be largely a function of the instrument calibrations rather than a real increase in ozone concentrations on the tract, particularly since only a slight increase was found at Site 3. The data collected over the past year are considered to be more accurate because of the rigorous quality assurance program that has been maintained during the MDP period, especially the traceability of the calibrations that has been achieved through a program of independent audits of the air quality instrumentation.

The primary hourly NAAQS of 0.08 ppm in effect during the current year was exceeded 36 times during the period at Site 1. There were no violations of the new hourly standard of 0.12 ppm. Of the 35 0.08 ppm NAAQS violations that occurred during this period, 28 were monitored between February 14 and March 16. It is felt that most of these twenty-eight violations may be attributed to the method of calibration. Until June, the ozone monitor was calibrated using the neutral buffered potassium iodide (NBKI) method. The Rockwell auditing team found the internal quarterly calibrations to be high when compared to their gas phase titration system, which is typical of the NBKI calibration technique (U.S. EPA 1978a). Beginning in June, the gas phase titration system was also used for internal ozone calibrations. This has produced excellent agreement with Rockwell's audits. These calibration results suggest that the monitor was reading somewhat high during the first part of the data collection period and that the number of violations of the 0.08 ppm NAAQS for ozone monitored during February and March was spuriously high. (However, the relative peak of ozone is still valid, and will be discussed in Section 3.2.)

In order to determine the effect of the internal NBKI ozone calibrations used for the first part of this one-year data set, a temporary data set was created in which the ozone data at Site 1 were corrected to reflect the results of the more traceable Rockwell audits. This resulted in a drop in the mean annual ozone concentration to 0.050 ppm. Although this represents a drop of 0.007 ppm from the mean annual ozone concentration of the official MDP data set, it is still well above the means of the two baseline years. The corrections to the temporary data set eliminated the 28 violations of the 0.08 ppm Federal standard.

An extensive analysis of the ozone data has been carried out in an attempt to develop a better understanding of the sources of ozone measured on the tract, particularly during periods of elevated concentrations.

3.1 Diurnal Variation

The most striking characteristic of the data is the diurnal variation of the ozone concentrations, which is much larger at Site 3 than at Site 1 (Figures 2-2 through 2-6). Both the diurnal variation and the absolute magnitude of the ozone concentrations are higher at each site in the summer months than the winter months. This diurnal variation was also found during the baseline period at Tract C-a (RBOSP 1977), and during the baseline period at Tract C-b (C-b Shale Oil Venture 1976).

However, during the current year the ozone concentration at Site 3 has always been below that at Site 1, which is in contrast to the baseline period, when the peak daily ozone concentration at Site 3 was typically above the peak daily concentration at Site 1. It is felt that the results during the current period are more representative of actual conditions in the region because of the quality assurance program discussed above.

The cause of this diurnal variation becomes an obvious but not easily answered question. Studies have shown that it is a common occurrence in urban areas, where the presence of ozone scavengers such as nitric oxide destroy most of the ozone near the surface at night. However, nitric oxide has not often been detected on the tract, so this mechanism cannot be an important factor.

Another interesting phenomenon is the difference in the relative magnitude of the diurnal variation at the two sites. Although conjectures have been made, such as photochemical production during the day, it is not immediately apparent why there is such a large difference in the diurnal variation of ozone between the two sites. An important clue to the mechanism involved is shown in Table 2-2. This table shows a typical "event" that occurs at night, in which sudden increases in the ozone concentration at Site 3 are detected, with little or no change in the

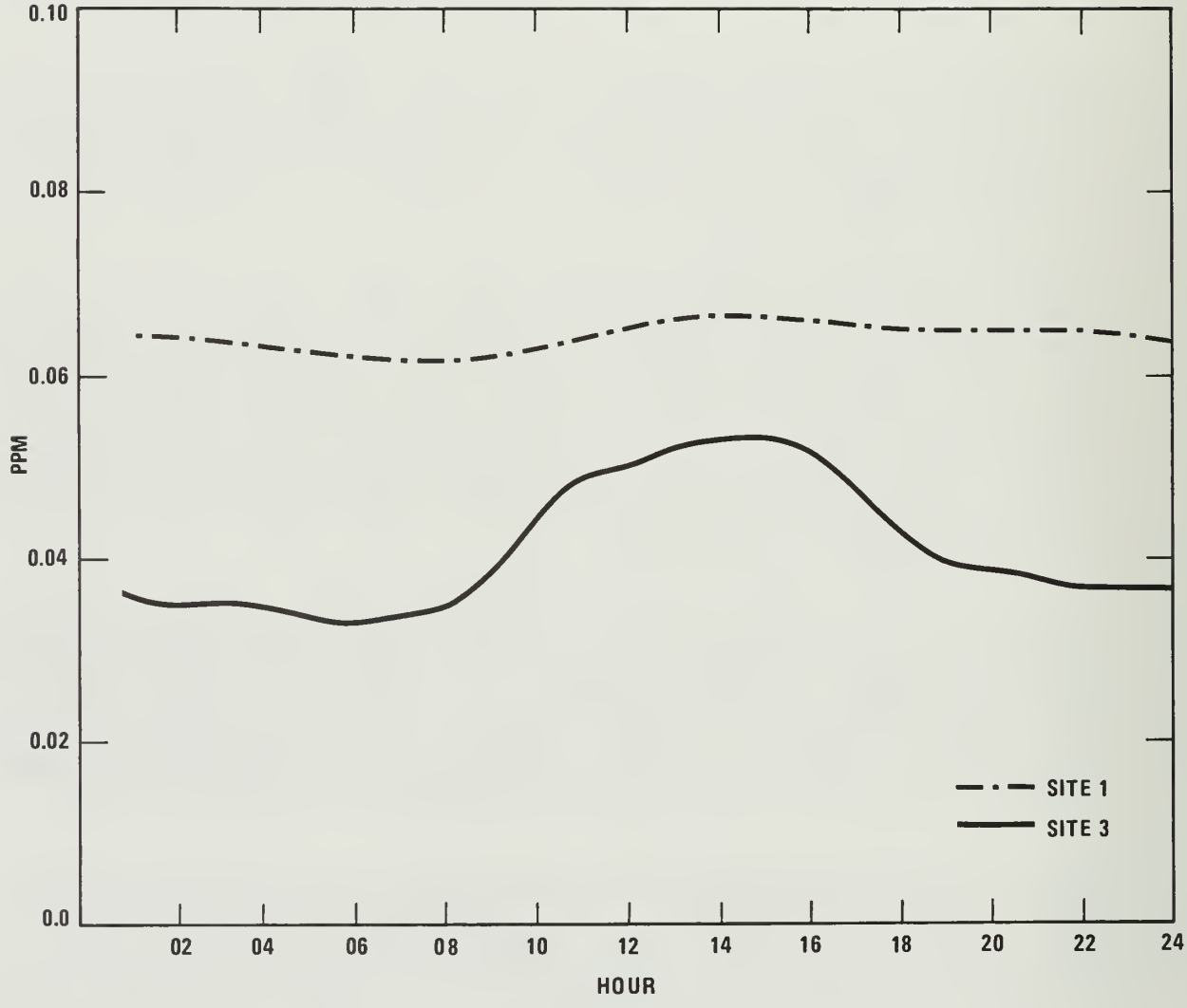


Figure 2-2 .

Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Tract C-a
Winter Season (Dec, 1977 and Jan-Feb, 1978)

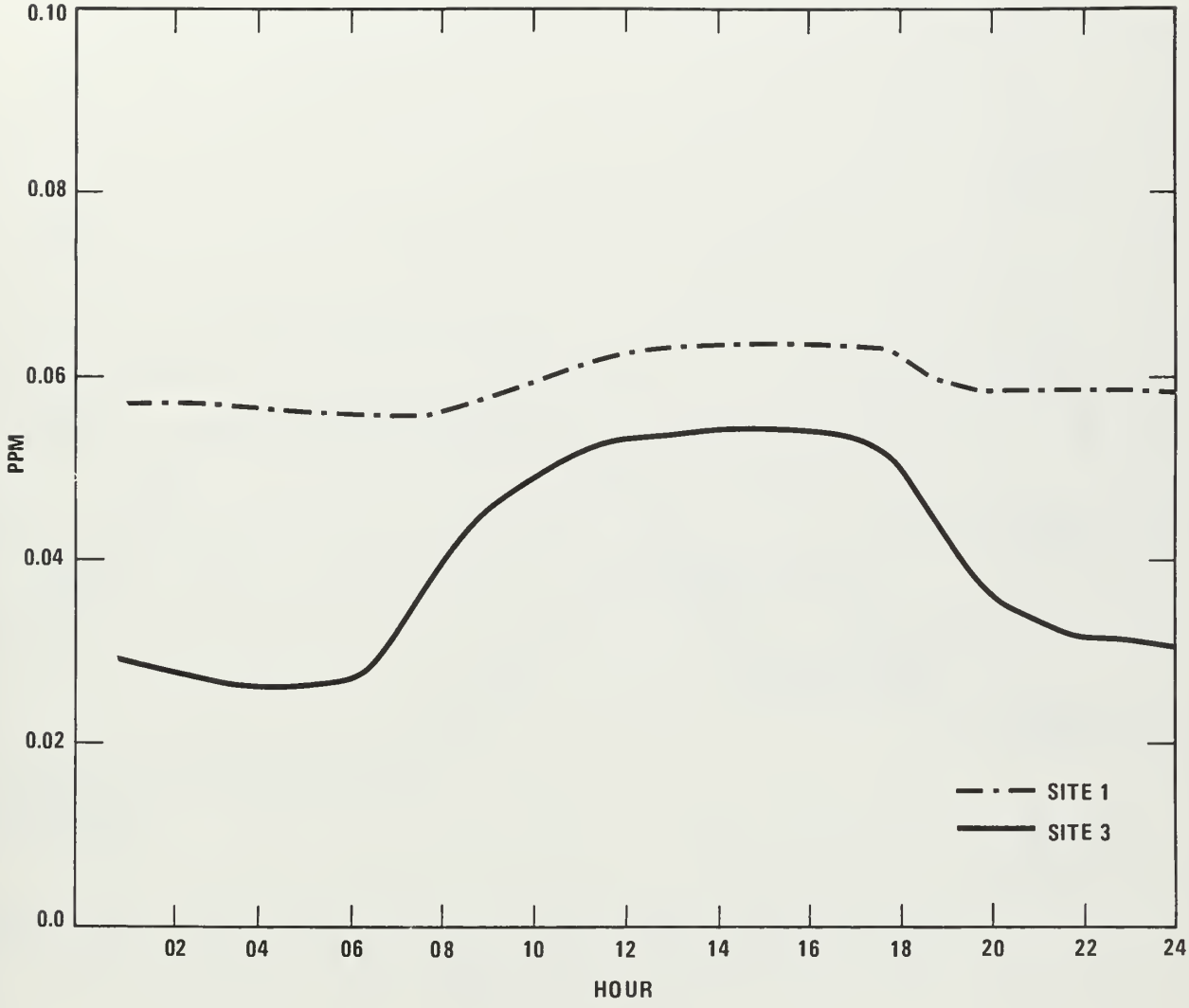


Figure 2-3.

Diurnal Variation of Mean Hourly Ozone Concentration at Sites 1 and 3, Tract C-a
Spring Season (Mar-May, 1978)

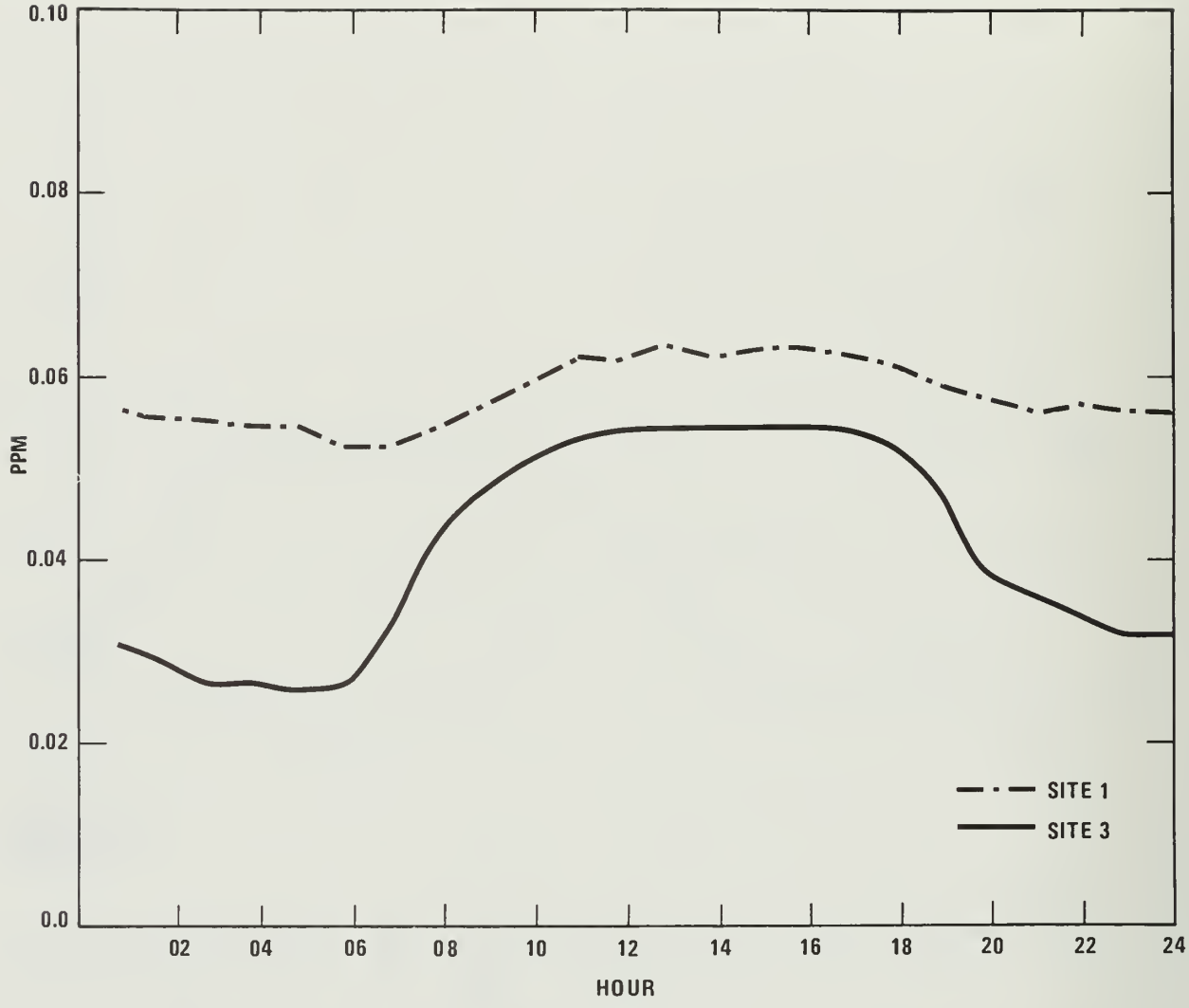


Figure 2-4.

Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Tract C-a
Summer Season (June-Aug, 1978)

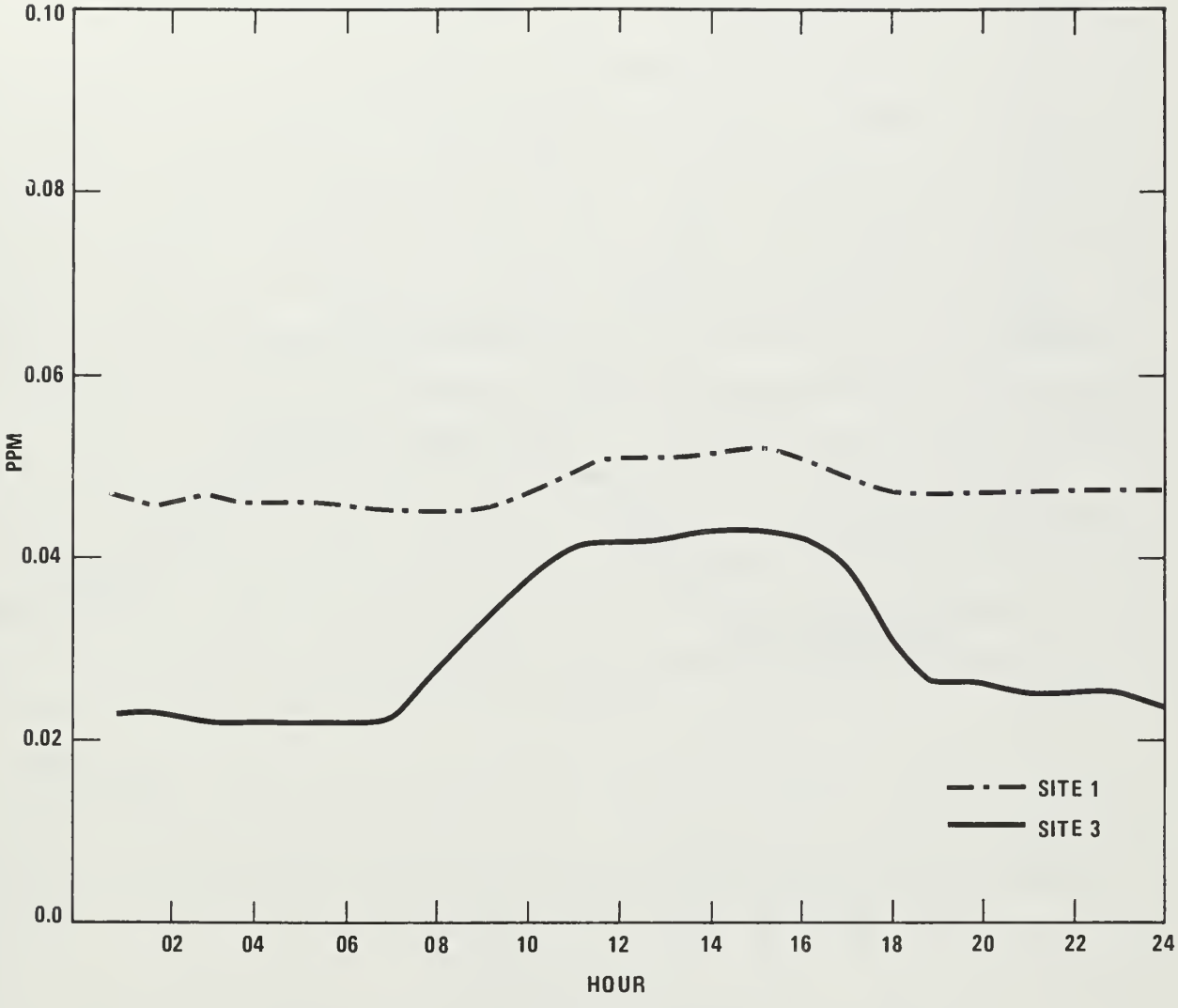


Figure 2-5.

Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Tract C-a
Fall Season (Sept-Nov, 1978)

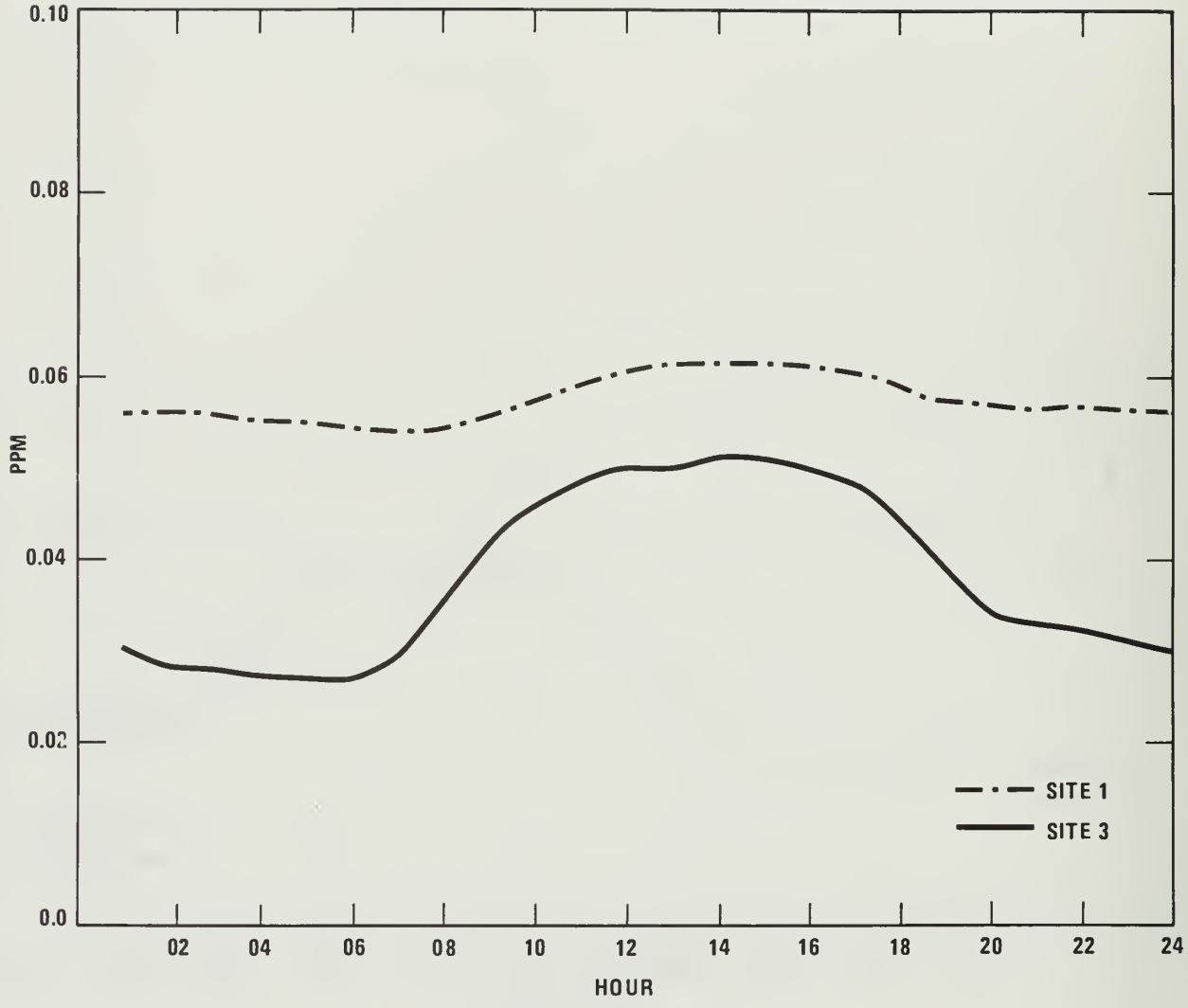


Figure 2-6.

Diurnal Variaton of Mean Hourly Ozone Concentrations at Sites 1 and 3, Tract C-a
Annual Average (Dec 1977-Nov 1978)

ozone concentration at Site 1. These events are frequent enough, perhaps several times a month, that they cannot be dismissed as anomalies. Because these events occur at night and do not occur at both sites simultaneously, the most popular mechanisms postulated for such changes involving stratospheric injection, changes in air mass, or photochemical production cannot be the controlling factors.

It can be seen in Table 2-2 that the ozone concentration at Site 3 increases simultaneously with a sharp decrease in the temperature differential between Site 1 and Site 3. (Site 1 is approximately 250 meters higher than Site 3, consequently the difference in 10m temperatures serves as an indicator of the atmospheric stability between the two sites.) This was the only meteorological parameter that was highly correlated with changes in the ozone concentration. Normally, ΔT_{1-3} is positive at night and slightly negative during the day. This suggests that an inversion lid develops over or within the gulch in which Site 3 is located, and inhibits the downward transport of ozone to Site 3 from an upper level "pool" or reservoir of ozone. The low nighttime ozone concentrations at Site 3 result from ozone destruction reactions at or near the surface. This hypothesis provides a simple mechanism to explain the nighttime jumps in ozone concentrations at Site 3. Destruction of the inversion in the gulch due to meteorological causes (such as wind shifts or wind speed increases) allows relatively ozone-rich air from above to be transported downward into the gulch and raise the ozone concentration very quickly.

This mechanism explains both the diurnal variation and the sudden nocturnal increases in ozone concentration at Site 3. In addition, it can account for the difference in the diurnal variations of ozone concentrations at the two sites. Apparently, Site 1 is not isolated from the pool of ozone, and so does not experience large decreases in ozone concentration at night. Even under extremely stable atmospheric conditions as measured by the Site 1 ΔT, or when large changes in stability occur, there were no significant changes in the ozone concentration measured at Site 1.

Support for this hypothesis can be found in the literature. Studies in northern New York (Coffey et al. 1977, Coffey et al. 1978) of ozone concentrations at two

TABLE 2-2. TYPICAL NOCTURNAL "EVENT" IN WHICH LARGE RAPID CHANGES IN THE OZONE CONCENTRATIONS AT SITE 3 OCCUR INDEPENDENTLY OF CHANGES AT SITE 1

Date	Hour	Site 3 O_3(ppm)	Site 1 O_3(ppm)	Site 1 Temp(^oC)	Site 3 Temp(^oC)	Site 1-Site 3 ΔT_{1-3}(^oC)	Site 1 ΔT_{60-10}(^oC)
7/28	2000	.035	.070	23.5	21.2	+2.3	+0.5
	2100	.034	.071	22.9	19.3	+3.6	+1.0
	2200	.023	.071	22.0	16.9	+5.1	+1.3
	2300	.039	.066	20.8	19.1	+1.7	+0.5
	2400	.045	.062	18.5	19.4	-0.9	+0.2
7/29	0100	.036	.061	17.2	17.0	+0.2	+0.3
	0200	.026	.056	16.4	15.6	+0.8	+0.6
	0300	.023	.056	16.5	15.0	+1.5	+0.5

remote sites, near the top of a mountain and in a valley, found the behavior of the data to be remarkably similar to the results from the two sites at Tract C-a. The site on the mountain was generally above the nocturnal inversion and showed very little diurnal variation, while the valley site was below the inversion and showed a strong diurnal pattern similar to Site 3. It was concluded for the valley site that "the daytime breakup of the inversion layer allows ozone replenishment from the ozone reservoir above this layer" (Coffey et al. 1977).

Another study found a strong correlation between increases in mixing depth and surface ozone concentrations in Michigan (Ott and Lyons 1977). The conclusion was that a large amount of ozone was stored in a pool above the nocturnal boundary layer.

Thus, it appears that large diurnal variations of ozone are a common phenomenon occurring in rural areas subject to nocturnal inversions. The hypothesis of an elevated pool of relatively high ozone concentrations explains both the observed diurnal variation at Sites 1 and 3 and the short-term nocturnal variations which have occurred at Site 3.

3.2 Longer-Term Fluctuations

The ozone data on the tract shows variations occurring over a longer period in addition to the diurnal fluctuations discussed above. A comparison of the relative importance of short-and long-term fluctuations in the ozone data set was made using a technique known as spectral analysis. This technique is commonly used on time series data. Through the use of a mathematical tool known as the Fourier Transform, this data is converted from the time basis on which it was collected to a frequency basis in which the relative contributions of each frequency to the variations of a data set can be computed. The rationale for using this technique is that physical explanations for fluctuations in the data set are more easily constructed on a frequency basis than a time basis.

The relative contributions to the fluctuations of each data set for specified frequencies at both sites were computed and are listed in Table 2-3. (It should

TABLE 2-3. PERCENT OF TOTAL VARIATION OF OZONE DATA AT SITES 1 AND 3 DUE TO VARIATIONS AT SELECTED PERIODICITIES

Period of Variation	Percent of Variation Compared to Total Variation Site 1	Site 3
All periods $\geq$ 1 day (diurnal + long-term variation)	77	74
Higher Harmonics of Diurnal Variation (contributes to rapid rise and fall of ozone concentrations)	4	7
Total Explainable Variation	81	81
Specific Components of Above Variation:		
1 day (diurnal variation)	12	44
4-8 days (synoptic scale variation)	31	10

be noted that the results presented are averages of the analyses of two six-month data periods rather than one twelve-month data period, due to size limitations of the computer program.) It can be seen that low frequencies up through one cycle per day (periods $\geq$ 1 day) are responsible for at least 75 percent of the total variation in the ozone data (this number is conservative due to "leaking" of the power spectral density). Part of the remaining spectral density occurs in higher harmonics of the diurnal variation, which are responsible for the rapid rise and fall of the ozone concentration in the morning and evening.

Table 2-3 shows that in the low frequency (long period) variation of the ozone concentrations at both sites, two periods are of major importance in contributing to the variation: a one-day period, corresponding to the diurnal ozone cycle, and a four to eight day period, corresponding to synoptic scale meteorological events. The relative importance of the diurnal cycle to the variations of ozone concentrations at Site 3 compared to the variations at Site 1 reflects the much larger amplitude of the diurnal cycle at Site 3. Although events in the synoptic scale range appear to be much less important in causing ozone variations at Site 3, to a certain extent this is an illusion due to the overwhelming influence of the diurnal ozone cycle at Site 3. That is, the absolute magnitudes of the effect of synoptic scale events on the ozone concentrations at both sites are very similar, with differences only in the percent of total ozone variation.

Review of the data sets has confirmed that significant changes in the ozone concentrations occur on a 4-8 day period. For example, high ozone concentrations approaching the NAAQS at Site 1 typically occur on several consecutive days. In addition, peaks in the ozone data could be observed at both sites simultaneously. The monthly maximum ozone concentrations often occurred at both sites on the same day. This phenomenon of variations in ozone concentration at frequencies corresponding to synoptic scale events has also been observed in at least one other remote site (Coffey et al. 1978).

Several periods showing significant changes in the ozone concentration at Site 1 were studied in an attempt to determine if any obvious changes in the meteorological conditions at Site 1 could be associated with these changes in

ozone concentrations. At times, there was a strong association, i.e., a wind shift and sharp temperature drop indicative of a frontal passage occurred simultaneously with an increase in ozone. However, at other times no significant change in the meteorological parameters could be found. This conclusion has also been reached by investigators at Tract C-b (Jones and Grossman 1976). The trajectories of the air for each of these periods were checked to determine if a change in the source region of the air was correlated with the change in ozone concentrations. A consistent pattern could not be established.

Thus, although a significant fraction of the variability in the ozone data was found at frequencies corresponding to synoptic scale events, no sources or events could be clearly linked with these changes. This is not entirely unexpected, since an ozone-rich air mass would have undergone a complex set of chemical reactions and atmospheric motions after leaving a source region. Another complicating factor is that the events in the synoptic scale range do not repeat on a regular basis, making determination of the source of ozone or its precursors more difficult. Other investigators in other areas of the country have also been unsuccessful in determining the causes for relatively long-term fluctuations in ozone concentration (U.S. EPA 1978b), although stratospheric injection, photochemical reactions, and long-range transport have been postulated.

Another interesting phenomenon is the relative increase in the Site 1 ozone concentrations during February and March (also seen at Site 3), mentioned earlier. This has also been noted during one of the baseline years at Tract C-b (C-b Oil Shale Venture 1976). Air trajectories were checked in an effort to find a source region for the high ozone concentrations, but no definitive pattern could be found, similar to the results of the analysis described above.

3.3 Conclusions

Much research needs to be done before an adequate understanding of ozone and its cycle through the atmosphere can be achieved. However, a number of recent advances in our knowledge allow certain conclusions to be made about the ozone concentrations at Tract C-a:

1) An elevated pool or reservoir of relatively high ozone concentrations probably exists over the region, which would eliminate or decrease the effect of any strategy designed to reduce onsite ozone concentrations.

2) the diurnal cycle of ozone concentrations observed at Site 3, and to a lesser extent Site 1, is the result of meteorological conditions that occur at the sites and not in situ production.

3) the longer-term fluctuations (including ozone concentrations exceeding the NAAQS) of ozone at the site are most likely generated offsite but their source is not clear at the present.

G. Particulates

The total suspended particulate matter (PM) in the atmosphere is of interest due to concern over health effects of the "respirable" fraction, effects on the general welfare, and the effects on visibility. Though the National Ambient Air Quality Standard (NAAQS) for PM does not differentiate among sources of the pollutant, recent regulations to accomplish the prevention of significant deterioration (PSD) of air quality distinguish between "fugitive dust" and other particulate matter. "Fugitive dust" is defined as particulates of native soil uncontaminated by the pollutants which result from industrial activity. The fugitive dust portion of PM is excluded from the ambient air quality analysis under current PSD regulations. Fugitive dust may originate from haul roads or exposed surfaces though the action of man or the wind or both. Since there is little industrial activity in the Tract C-a region, most of the particulate sources in the area are classified as fugitive dust sources.

1. Objectives

The objective of PM monitoring is to establish the background levels and the effects of construction and operation on the ambient air quality during the Modular Development Phase of tract operations.

2. Methods

The PM load of the ambient air is measured by the federal reference method of high volume sampling. During the MDP monitoring period PM measurements were made every sixth day until late March, when the frequency was increased to once every fourth day and all sites were placed on the same date schedule. There are four sites where particulate data are taken: Sites 1 and 2, which are generally upwind of the construction area; Site 3, which may be exposed to particulates generated on the tract access roadway (about 100 yards away) or to particulates generated at the construction area under certain valley flow conditions; and Site 6, which is adjacent to the main construction area. With the concurrence of the Area Oil Shale Supervisor (AOSS), Site 6 monitoring was discontinued as of October 10, 1978.

3. Results and Discussion

Quarterly and annual geometric mean and maximum values of the PM data for the current year at each of the four sites are presented in Table 2-4. The highest values are those for Site 6, which is immediately adjacent to the main MDP construction site. Second highest are the values for Site 3, which is located just offsite in the main valley draining northeastward from the construction area. The Site 3 values are generally much lower than those for Site 6. The annual geometric mean of the Site 3 data is less than one-third that of the Site 6 data, and the annual Site 3 maximum is less than one-tenth the annual Site 6 maximum. Sites 1 and 2 have the lowest geometric means and maximum values of the concentration data for the four sites. The annual geometric means of the data for each of these sites are about half that for the Site 3 data, and the annual maxima are each less than forty percent of that for the Site 3 data. The annual means and maximum values of the data for Sites 1 and 2 are approximately equal.

The highest geometric means and maximum values of the particulate concentration data for each of the four sites occur in the fourth MDP quarter, which spans the warm, dry, summer months. The lowest values occur in the second MDP quarter, during the winter months when there is a semi-permanent snow cover.

TABLE 2-4. QUARTERLY AND ANNUAL GEOMETRIC MEANS AND MAXIMUM VALUES OF 24-HOUR AVERAGE TOTAL SUSPENDED PARTICULATE CONCENTRATIONS FROM DECEMBER 1977 TO NOVEMBER 1978 ($\mu g/m^3$)

	Site 1	Site 2	Site 3	Site 6
Second Quarter MDP (December 1977 to February 1978)				
Geometric Mean	3.6	2.9	5.4	14.1
Maximum	8.5	4.7	32.6	27.5
Third Quarter MDP (March 1978 to May 1978)				
Geometric Mean	11.6	10.6	15.5	61.0
Maximum	38.0	39.1	54.2	1220.
Fourth Quarter MDP (June 1978 to August 1978)				
Geometric Mean	21.6	22.1	77.4	236.
Maximum	58.6	60.2	160.	1805.
Fifth Quarter MDP (September 1978 to November 1978)				
Geometric Mean	17.2	15.1	39.1	212.
Maximum	50.5	33.6	155.	1095.
Annual (December 1977 to November 1978)				
Geometric Mean	13.6	12.9	26.3	95.0
Maximum	58.6	60.2	160.	1805.

Quarterly and annual geometric means and maximum values of the baseline data for Sites 1, 2 and 3 are presented in Table 2-5 (RBOSP 1977). Comparison of the annual geometric means during the baseline and MDP periods shows that Site 3 concentrations are higher than either Site 1 or Site 2 concentrations for both periods. In fact, the first baseline year and the current MDP year are similar in that the annual mean Site 3 concentration is double those of Sites 1 and 2. It is also interesting to note that the maximum concentrations at Site 3 during each of the baseline years exceed the maximum concentrations at Site 3 during the MDP period. Thus, the local topography and meteorology combine to increase the particulate concentrations measured at Site 3 relative to Sites 1 and 2, regardless of the level of activity on the tract.

However, there is a significant increase in the annual geometric mean concentration at all three sites between the baseline period and the MDP period. The increase is relatively small at Sites 1 and 2 (approximately 4 $\mu g/m^3$) and moderate at Site 3 (8-14 $\mu g/m^3$). The variability of the mean concentrations at Site 3 during both the baseline and MDP periods is much greater than at the other two sites.

Table 2-6 lists the number of primary and secondary NAAQS violations measured at each of the sites during the current year, and the percent of the data for each site represented by the violations. Most violations were recorded at Site 6, with 27 percent of the data for the site exceeding the federal 24-hour average primary standard for particulates of 260 $\mu g/m^3$, and 41 percent exceeding at least the secondary standard of 150 $\mu g/m^3$. Site 6 is considered anomalous in that it is located immediately adjacent to the MDP construction site. Air quality monitoring at Site 6 is strongly affected by the generation of fugitive dust from the nearby construction activity and is not representative of ambient air quality conditions. As a result, monitoring at Site 6 has been discontinued with the approval of the AOSS. The only other violation recorded was one violation of the secondary standard at Site 3.

The cumulative frequency distributions of the particulate concentration data for the four sites are presented in Figures 2-7 through 2-10. The figures illustrate the relatively high concentrations measured at Site 6, the intermediate ones

TABLE 2-5. QUARTERLY AND ANNUAL GEOMETRIC MEANS AND MAXIMUM VALUES OF 24-HOUR AVERAGE TOTAL SUSPENDED PARTICULATE CONCENTRATIONS FOR THE BASELINE PERIOD (FEBRUARY 1975 TO JANUARY 1977) ($\mu g/m^3$)

	Site 1	Site 2	Site 3
February 1975			
Geometric Mean	--	2.7	5.3
Maximum	--	10.1	12.3
Spring 1975 (March-May)			
Geometric Mean	29.3	11.4	23.1
Maximum	95.3	84.2	163.
Summer 1975 (June -August)			
Geometric Mean	21.7	14.9	46.9
Maximum	211.	95.4	247.
Fall 1975 (September-November)			
Geometric Mean	6.2	15.8	18.4
Maximum	52.0	102.	137.
Winter 1975-76 (December-January)			
Geometric Mean	1.9	2.0	4.3
Maximum	9.6	10.7	13.5
Spring 1976 (March-May)			
Geometric Mean	11.	11.	11.
Maximum	80.	51.	130.
Summer 1976 (June-August			
Geometric Mean	22.	22.	27.
Maximum	81.	57.	105.
Fall 1976 (September-November)			
Geometric Mean	12.	15.	35.
Maximum	53.	46.	281.
Winter 1976-77 (December-January)			
Geometric Mean	5.	6.	5.
Maximum	18.	57.	59.

TABLE 2-5 (Continued)

1975-76 Annual			
Geometric Mean	9.	9.	18.
Maximum	211.	102.	247.
1976-77 Annual			
Geometric Mean	8.	9.	12.
Maximum	81.	57.	281.

Data in table taken from Reference 1.

TABLE 2-6. VIOLATIONS OF FEDERAL PRIMARY AND SECONDARY STANDARDS FOR 24-HOUR AVERAGE TOTAL SUSPENDED PARTICULATE CONCENTRATIONS, FROM DECEMBER 1977 TO NOVEMBER 1978

	Site 1	Site 2	Site 3	Site 6
Number of Samples	67	72	72	56
Federal Primary 24-Hour Average TSP Standard (260 $\mu g/m^3$)				
Number of Violations	0	0	0	15
Percent of Samples	0%	0%	0%	27%
Federal Secondary 24-Hour Average TSP Standard (150 $\mu g/m^3$)				
Number of Violations	0	0	1	23
Percent of Samples	0%	0%	1%	41%

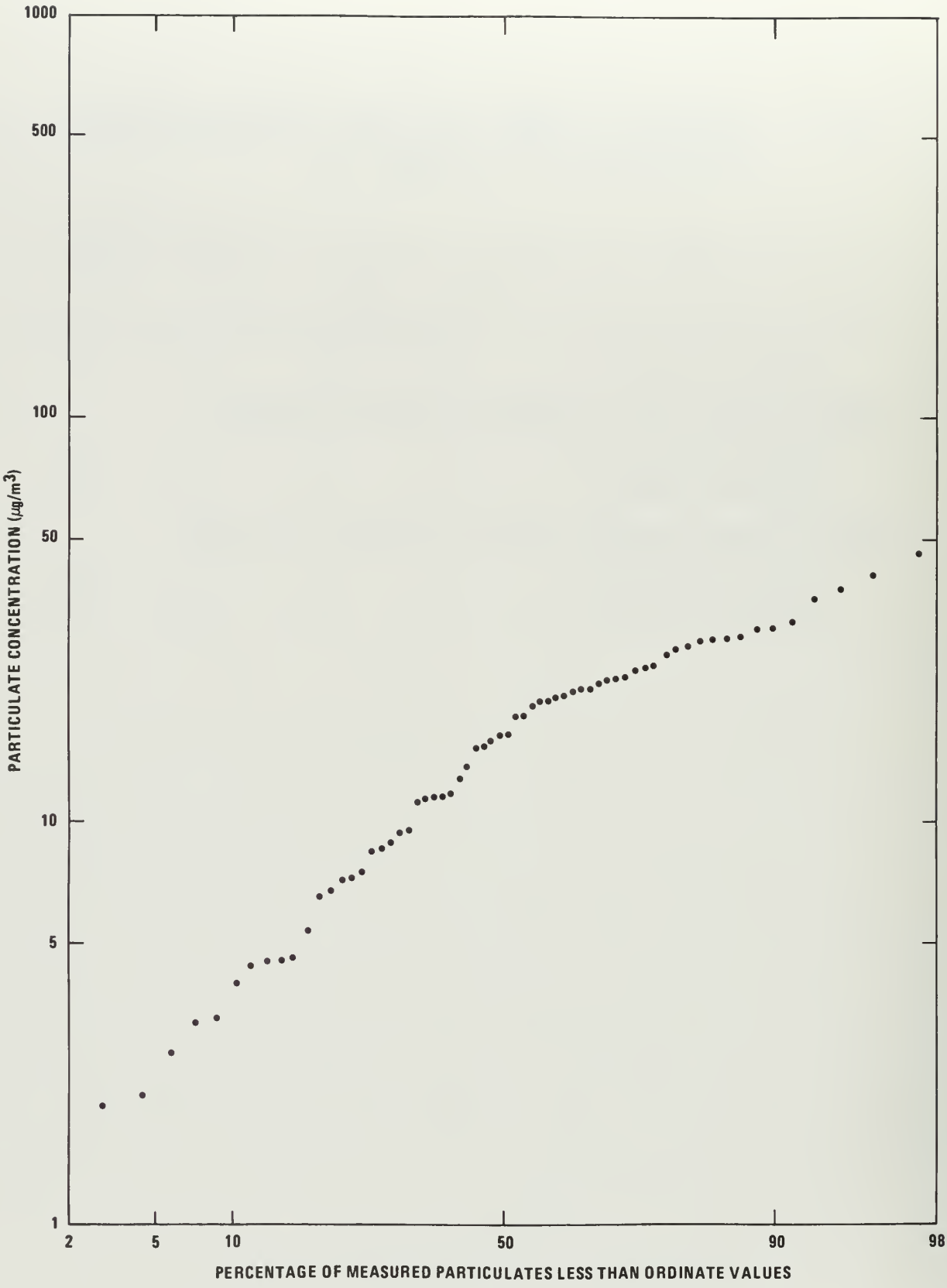


Figure 2-7. Cumulative Frequency Distribution of Particulates for Site 1

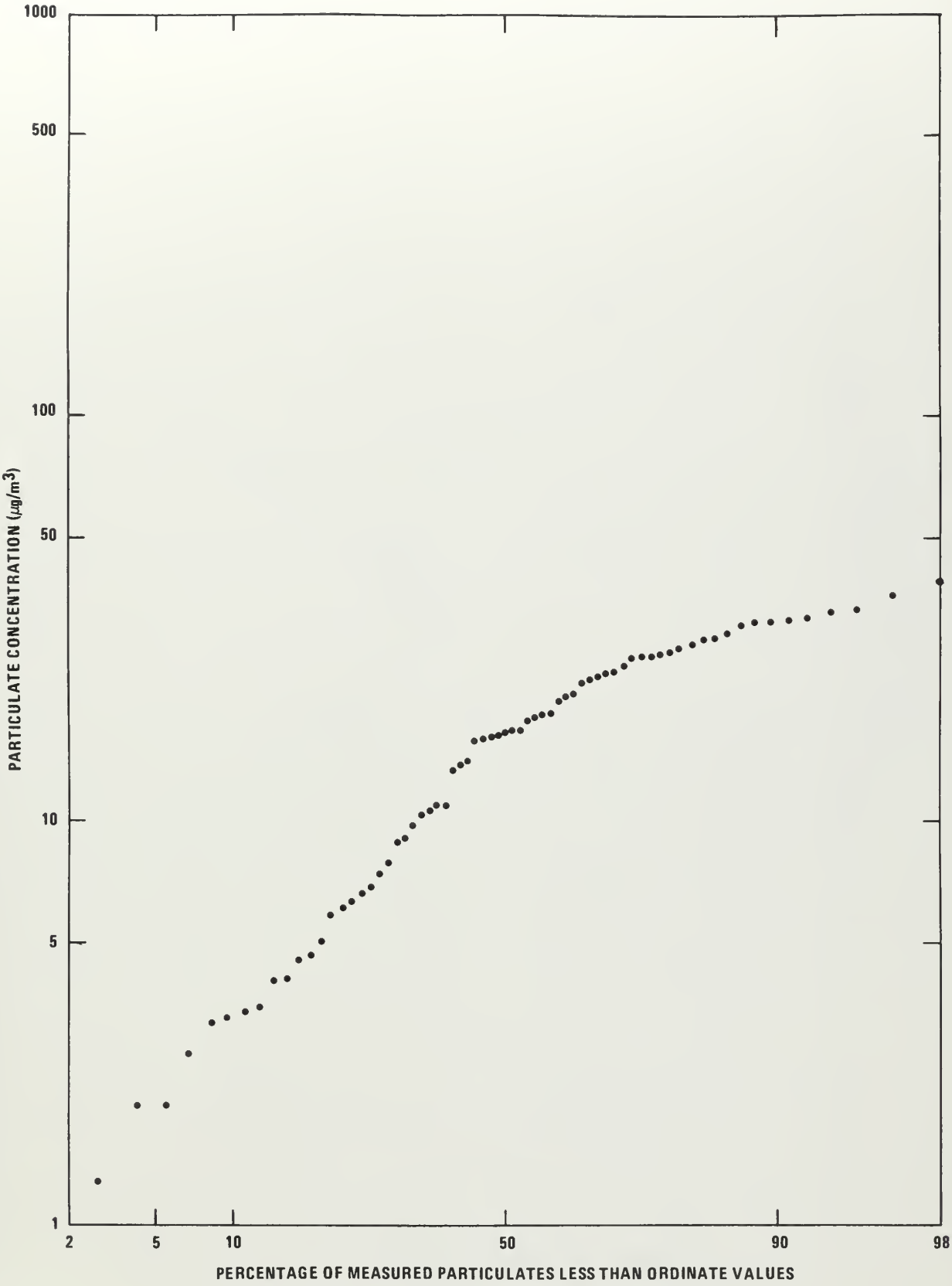


Figure 2-8. Cumulative Frequency Distribution of Particulates for Site 2

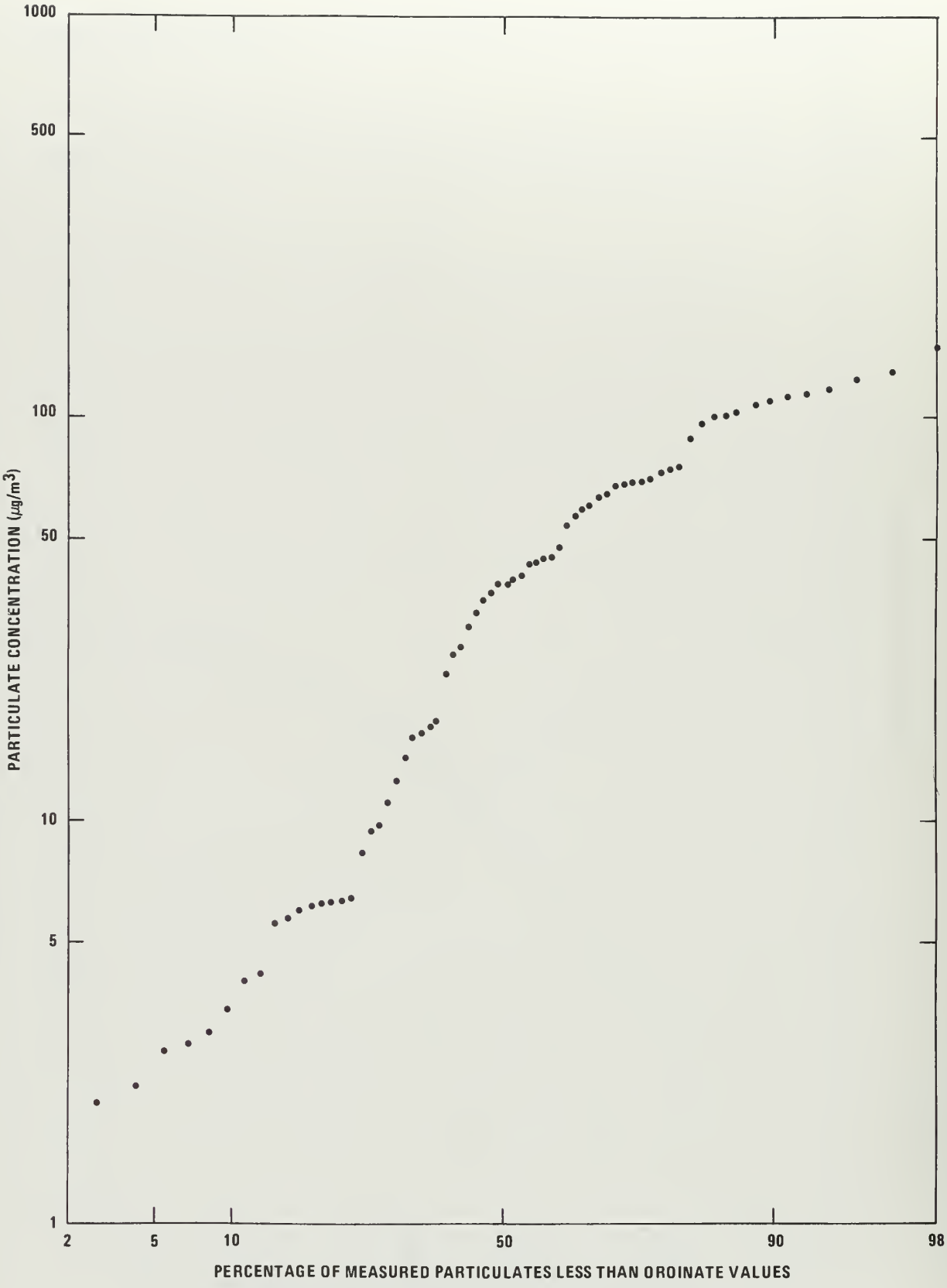


Figure 2-9. Cumulative Frequency Distribution of Particulates for Site 3

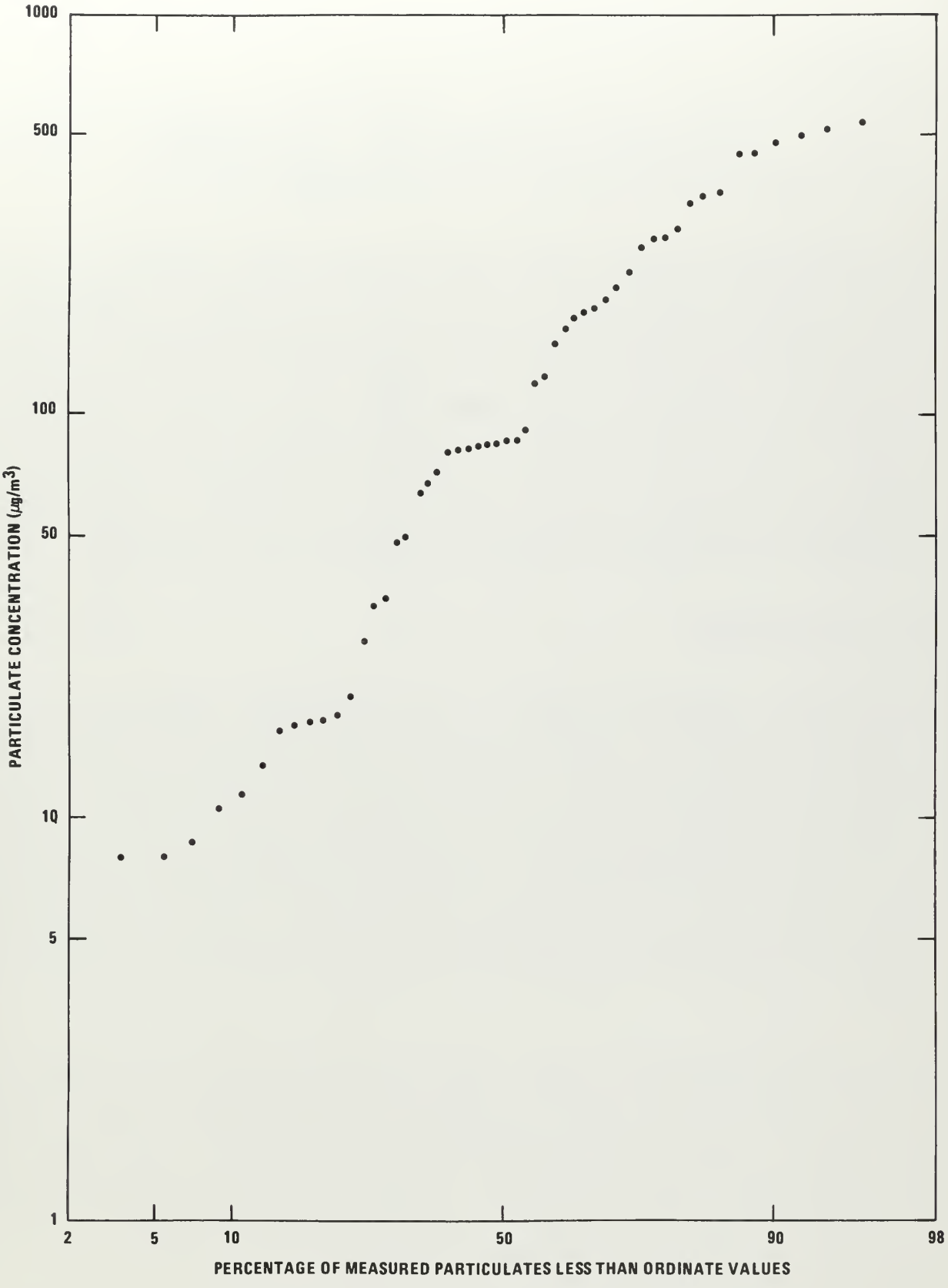


Figure 2-10. Cumulative Frequency Distribution of Particulates for Site 6

measured at Site 3 and the relatively low ones measured at both Sites 1 and 2. Comparison with similar plots for the first year baseline data reveals that the MDP Site 3 frequency distribution is shifted upward, and the MDP Sites 1 and 2 frequency distributions do not show the high particulate concentrations (> 50 $\mu g/m^3$) evident during the first baseline year.

One major and obvious factor affecting the total suspended particulate concentration is the presence of a snow cover on the ground. Comparison of the distributions of the particulate concentration data during periods of snow cover and no snow cover for the four sites reveals that at least 85 percent of the particulate concentration measurements made during the periods without snow cover exceed the highest concentration measured during periods with snow cover. Figure 2-11 shows the relative distributions of the particulate concentrations measured during periods with and without snow cover for Site 3, which illustrates the higher concentrations measured during periods of no snow cover.

3.1 Correlations

Correlations between the sites of the particulate concentration data are presented in Table 2-7. Because it was felt that there were different physical processes operating during the snow-covered winter months (and few concurrent samples), the correlations are limited to the period with no snow cover (March 25 to November 8, 1978) during which concentrations were measured concurrently at all four sites. Measurements at all sites were obtained on 35 of the 59 sampling days in this period, or 59 percent of the cases. The correlations are thus considered representative of the period for which there was no snow cover on the site.

Concentrations measured at Sites 1 and 2 are the most highly correlated, with a correlation coefficient (r_{12}) of 0.86 which signifies that the concentration data for Site 2 is proportional to corresponding data for Site 1. The scatter diagram for concentrations at the two sites is presented in Figure 2-12, which shows high correlation between the two data sets. In contrast the particulate concentration at Site 3 is only weakly correlated to the concentrations at Sites 1 and 2. The correlation coefficient for the Site 3 and Site 2 particulate concentrations (r_{32}) is 0.40, and for the Site 3 and Site 1 concentrations (r_{31}) is 0.36.

TABLE 2-7. CORRELATION COEFFICIENTS (r) AND COEFFICIENTS OF DETERMINATION (r^2) FOR THE 24-HOUR AVERAGE TOTAL SUSPENDED PARTICULATE CONCENTRATIONS AT SITES ONE, TWO, THREE AND SIX

Correlation	r	r^2
TSP2 - TSP1	.86	.74
TSP3 - TSP2	.40	.16
TSP3 - TSP1	.36	.13
TSP6 - TSP3	.34	.12
TSP6 - TSP1	.23	.05
TSP6 - TSP2	.12	.01

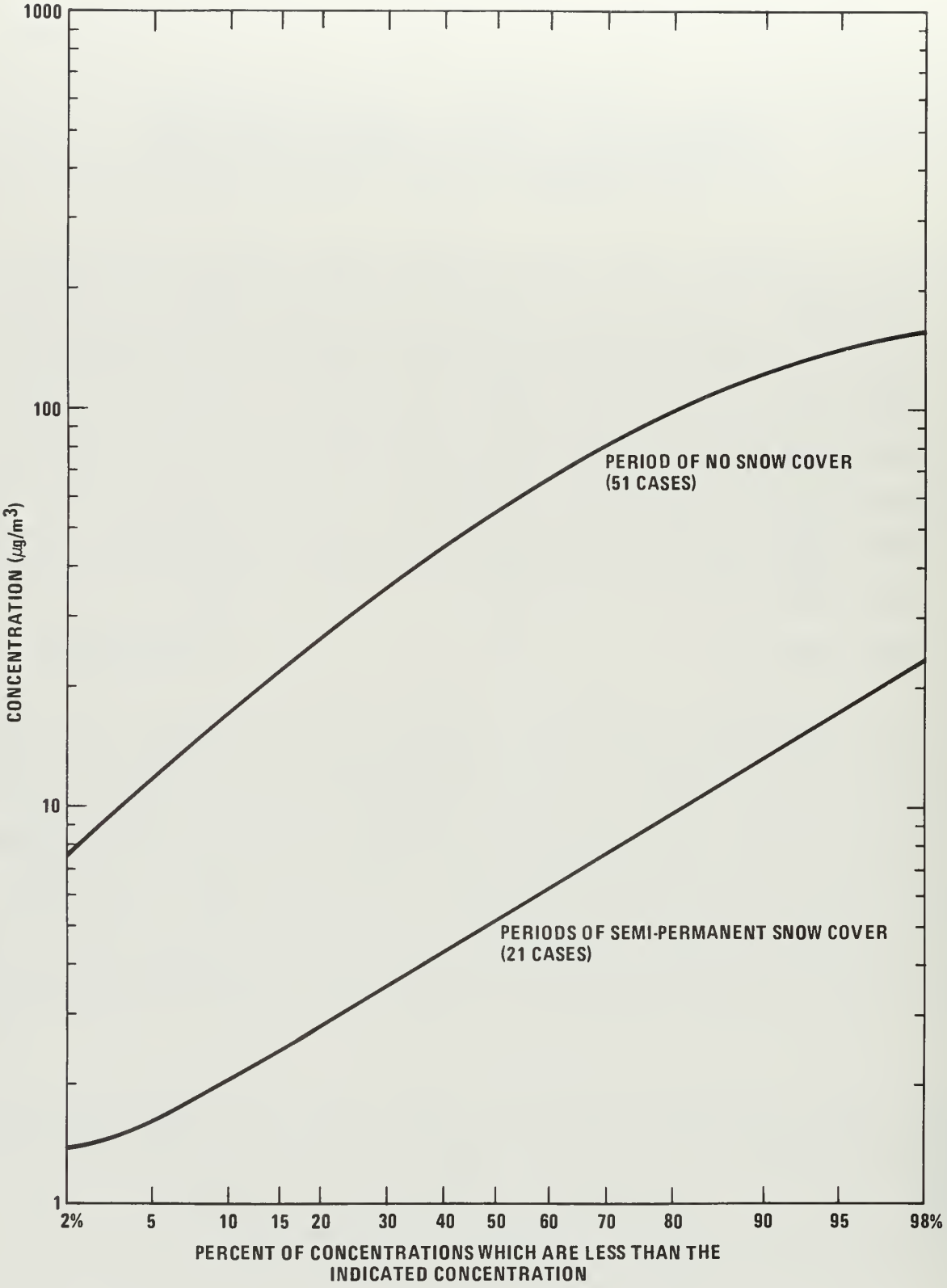


Figure 2-11.
Cumulative Distributions of the Particulate Concentrations Measured at Site 3
for the Periods of Semi-Permanent Snow Cover and for the Remaining Period of No Snow Cover

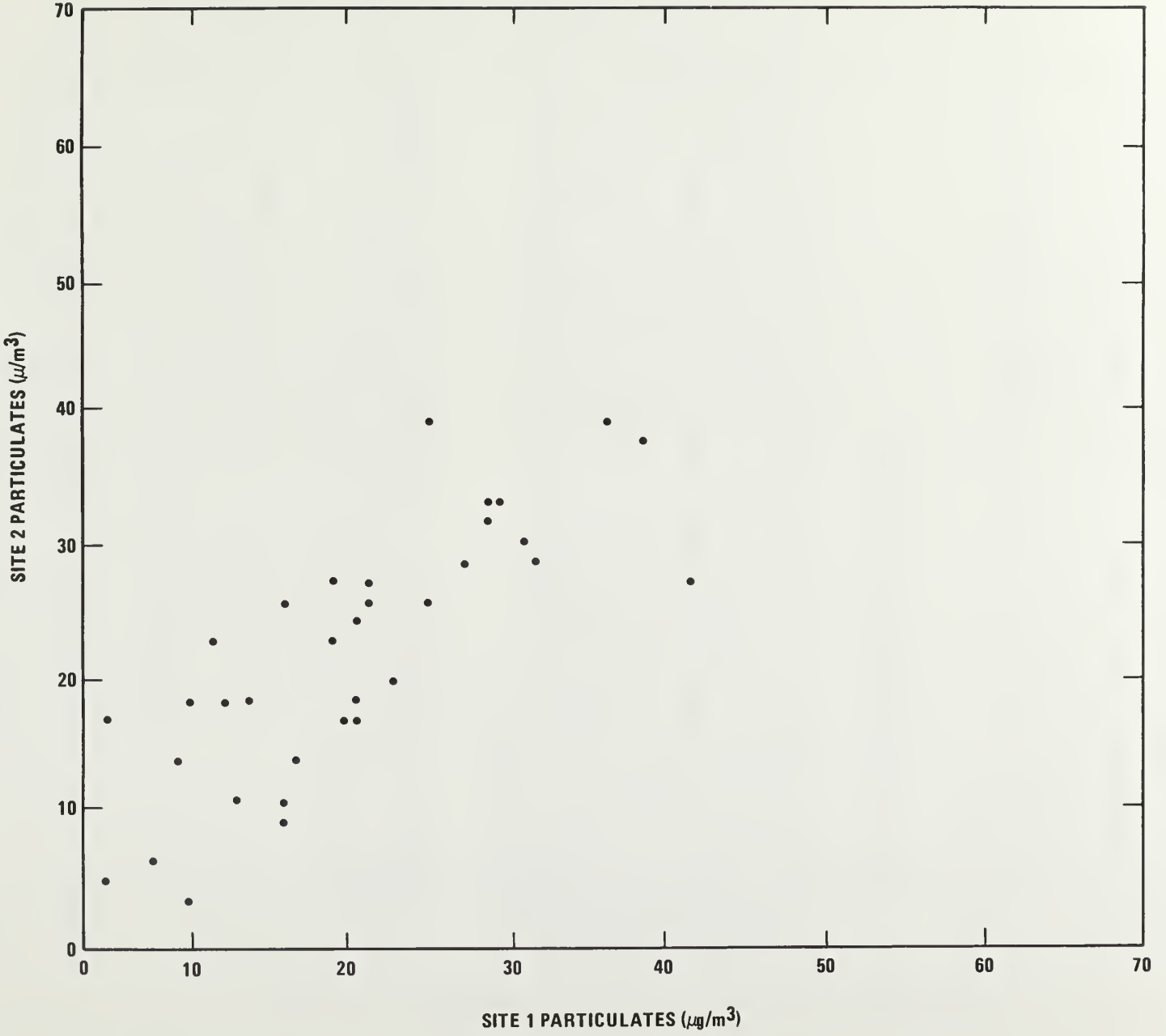


Figure 2-12. Correlation of Particulate Concentrations at Sites 1 and 2

The weakest correlations were found between the Site 6 particulate data and the data from the other sites (Table 2-7). This result is reasonable, since the location of Site 6 (adjacent to the main construction area) means that it will measure local sources of fugitive dust that will not reach the other sites. The correlation between Site 6 and Site 3 is higher than with the other two sites, which is expected because Site 3 is often in the downvalley flow, which drains the area around the construction area. However, the correlation between the data from these sites is less than those between the data for Sites 3 and 1 and Sites 3 and 2.

3.2 Data Trends and Possible Predictors

The scatter diagrams of particulate concentrations measured at Site 3 plotted against those measured at Sites 1 and 2 illustrate the weak correlations of the Site 3 data to the concurrent data for the other two sites (Figures 2-13 and 2-14). In addition, each of the figures reveal two distinct correlation tendencies at higher particulate concentrations for Site 1 and Site 2. One subset of the particulate data in these scatter diagrams has an approximate one-to-one correspondence in the concentrations, while the other subset has a ratio of approximately five to one between the concentrations measured at Site 3 and at the other two sites.

This apparent relationship was investigated further by defining a set of parameters to establish the meteorological conditions and site activity during each sampling day. These parameters were defined as:

PREC 1 - precipitation on the sampling day (hundredths of an inch)

PREC 2 - total precipitation on the sampling day and the previous day (hundredths of an inch)

WKDYND - weekday/weekend indicator (1 for weekday, 2 for weekend)

WRKRS - number of workers onsite

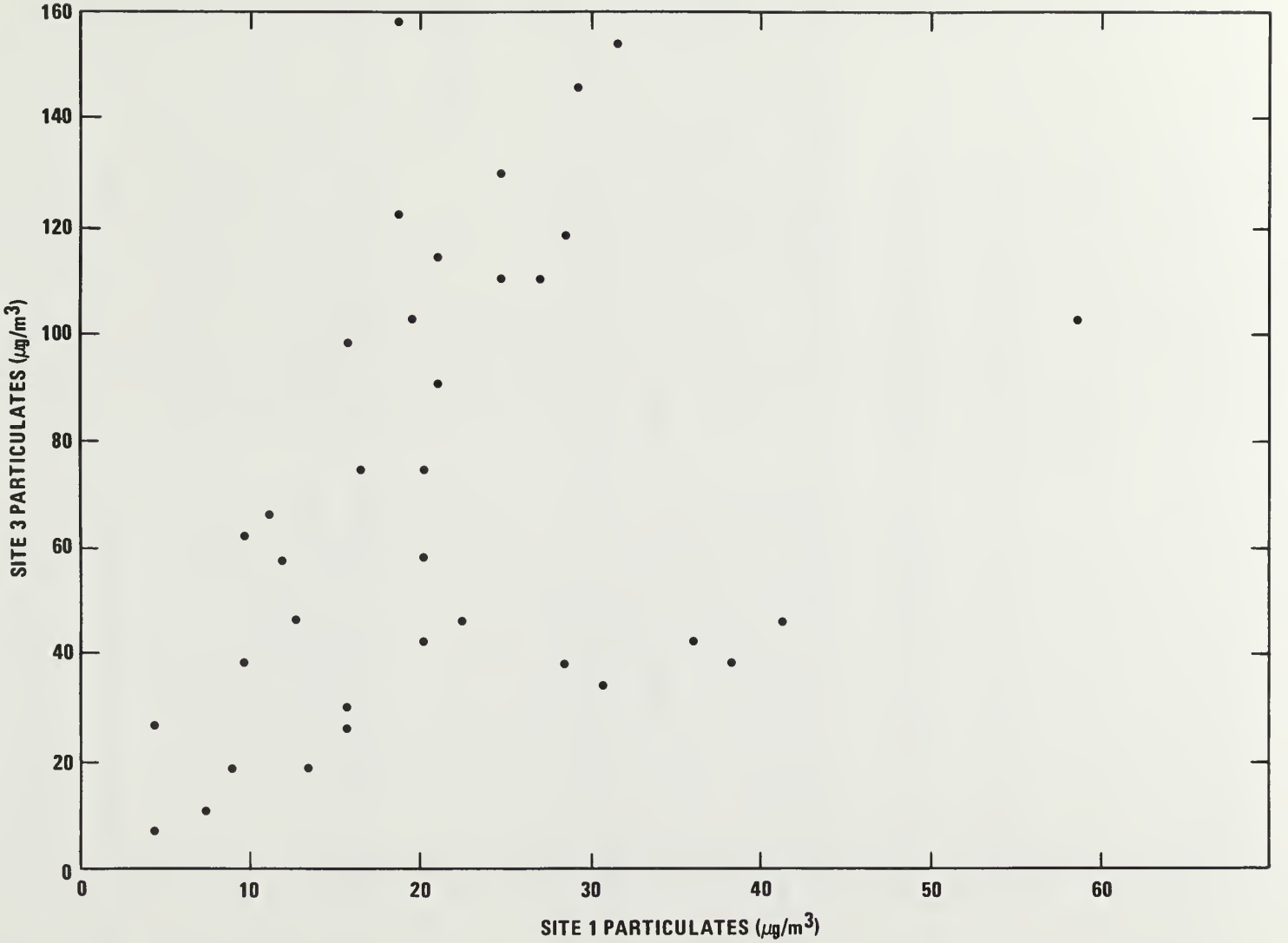


Figure 2-13. Correlation of Particulate Concentrations at Sites 1 and 3

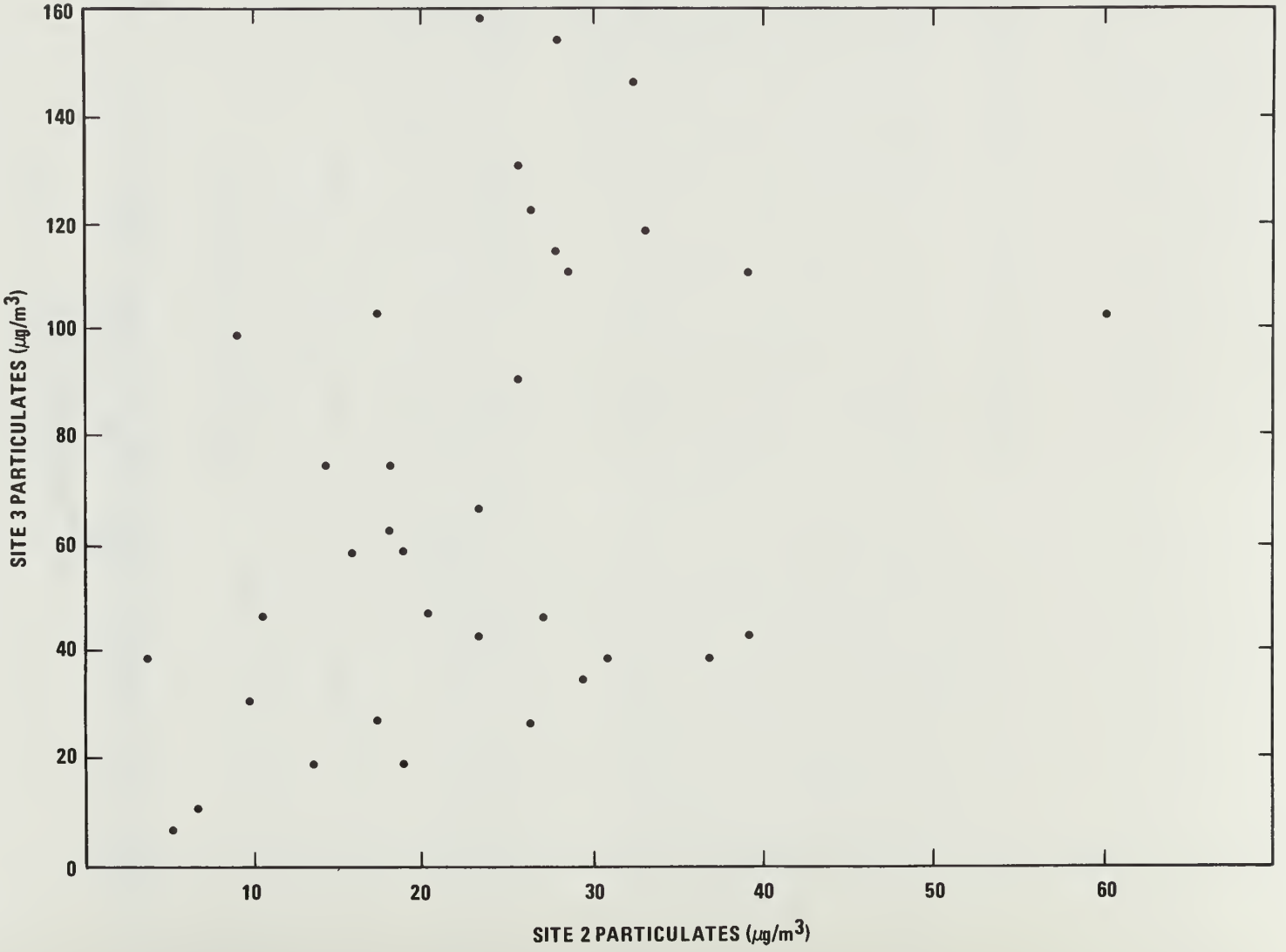


Figure 2-14. Correlation of Particulate Concentrations at Sites 2 and 3

HRS3NE - number of hours of winds blowing out of directions from 0^{o} to 80^{o} between 7:00 AM and 5:00 PM measured at Site 3 (upslope winds towards the construction area)

WS3DAY - average of hourly wind speeds from 7:00 AM to 5:00 PM measured at Site 3 (mph)

INSOL - total insolation (ly/day)

WS2 - 24-hour average wind speed, measured at Site 2 (mph)

TEMP - 24-hour average temperature, measured at Site 2 (^{o}C)

The values of these parameters for each sampling day falling into one of the two groups are listed in Table 2-8. (Group 1: Site 3 particulate concentrations much higher than concentrations from Sites 1 or 2; Group 2: Site 3 particulate concentrations approximately equal to concentrations from Sites 1 or 2). With one exception, Group 1 consists of weekdays with high numbers of workers (> 100) onsite. (A negligible amount of precipitation occurred on two of these days.) Group 2 consists of weekend days or weekdays with precipitation, again with one exception.

3.3 Regression

Several aspects of the particulate data presented in the foregoing subsections indicate an influence of meteorological parameters and MDP construction activity on particulate concentrations at Site 3. Plotted against concentration data for Sites 1 and 2, the higher Site 1 or Site 2 particulate concentrations exhibit two groups tending toward different concentration ratios. Examination of the values of meteorological and site activity predictor variables for the two groups of cases presented in Table 2-8 indicate that the MDP construction activity (number of workers onsite) and vehicular traffic characteristic of weekdays (weekday vs. weekend) affect particulate concentration levels at Site 3 more than at Sites 1 and 2. The relative importance of construction activity and meteorological

TABLE 2-8. METEOROLOGICAL AND SITE ACTIVITY PARAMETERS AND PARTICULATE CONCENTRATIONS FOR SELECTED DAYS AT TRACT C-a

	TSP3	TSP1	TSP2	PREC1	PREC2	WKDYND	WRKRS	HRS3SW	HRS3NE	WS3DAY	INSOL	WS2	TEMP2
Group 1													
7/11	89.0	21.1	25.7	3	6	1	149	-	-	-	-	-	-
8/24	97.5	15.5	9.1	0	0	1	151	10	0	11.7	10.2	12.8	21.1
8/28	104.0	19.5	16.9	0	0	1	140	-	-	-	9.6	5.2	16.5
9/1	109.0	27.1	28.6	0	0	1	145	4	2	9.5	8.8	10.8	20.7
8/8	110.0	24.4	38.7	0	0	1	-	1	4	5.6	6.8	5.7	22.4
10/11	114.0	21.3	27.5	0	0	1	192	3	1	7.2	6.6	11.0	14.3
7/15	119.0	28.8	33.2	0	0	2	45	6	2	10.9	8.0	9.3	23.9
6/21	124.0	18.4	26.3	0	0	1	156	9	2	9.5	12.1	11.3	22.0
8/4	130.0	24.6	25.7	0	0	1	-	0	7	6.8	11.3	6.9	20.4
7/27	147.0	29.1	32.4	0	0	1	-	1	7	5.3	11.1	7.6	75.2
9/5	155.0	31.7	28.1	0	0	1	152	8	1	9.5	9.3	10.0	24.0
6/29	160.0	18.5	22.9	7	7	1	160	4	3	5.3	4.4	5.7	14.8
Group 2													
9/17	35.2	30.6	29.5	11	23	2	47	7	1	11.9	6.3	15.9	13.5
7/3	38.6	28.4	31.0	0	0	2	8	11	0	14.4	12.6	16.3	21.7
4/26	38.7	38.0	36.8	18	18	1	167	11	0	14.3	8.4	16.0	12.2
5/24	40.5	36.0	39.1	0	0	1	193	-	-	14.1	-	15.7	-
9/9	47.9	41.5	27.0	1	2	2	84	8	1	10.9	7.7	10.1	19.0
6/25	101.0	58.6	60.2	0	0	2	41	0	0	12.4	12.2	13.5	18.1

factors in accounting for the concentrations measured at each site is evaluated by the use of multiple and stepwise multiple regressions.

Statistics based on multiple regressions of particulate concentrations for Sites 1, 2 and 3 against meteorological parameters alone and meteorological and site activity indicators together are presented in Table 2-9. Coefficients of multiple regression are presented, as well as confidence levels for acceptance of the site activity predictors. The data base of the statistics for each site is limited to the period characterized by a lack of snow cover, and includes only cases for which values are available for both the particulate concentration measured at each site and all the meteorological and site activity predicator variables. For each site, these cases comprise three-fourths of the sampling days during the period of no snow cover and are thus considered representative.

Comparison of the statistics for the three sites (Table 2-9) indicate the following:

- The fraction of the variation in particulate concentration data explained by concurrent meteorological variables, given by the multiple regression coefficient $r^2_{Y\ met}$, is greatest for Site 3 (0.64) and smallest for Site 1 (0.43).

- The fraction of the variation in concentration explained by the site activity indicators (after the meteorological variables have been regressed against the particulate data) is greatest for Site 1. In fact, the confidence that the site activity predictors contribute additional information if added to the regression with the meteorological predictors alone is significant only for the Site 1 data. (The confidence is 98 percent for the Site 1 data but 60 percent or less for both the Site 3 and Site 2 data.)

Thus, about half of the variation in concentration data is explained by the meteorological predictor variables at each of the three sites, but the site activity indicator variables account for a significant fraction of the remaining

TABLE 2-9. STATISTICS CONCERNING THE RELATIVE CONTRIBUTIONS MADE BY ADDING THE PREDICTOR VARIABLES INDICATIVE OF SITE ACTIVITY TO REGRESSIONS OF PARTICULATE CONCENTRATION FOR SITES 1, 2 AND 3 BASED ONLY ON THE METEOROLOGICAL PREDICTOR VARIABLES

Statistic	Symbol	Interpretation	Value of Statistic for: Site 1	Site 2	Site 3
Dependent Variable	Y	24-hr avg. particulate concentration	TSP 1	TSP 2	TSP 3
Sample size	n	Number of cases without snow cover for which values of both the dependent variable and all predictors are available	40	41	38
Coefficient of multiple regression for regression of Y variable against meteorological predictor variables alone[1]	$r^2_{Y\ met}$	Fraction of the total variation in Y accounted for by its regression against meteorological predictor variables alone	.43	.54	.64
Coefficient of multiple regression for regression of Y variable against all predictor variables, both meteorological and site activity-indicative	$r^2_{Y\ all}$	Fraction of total variation in Y accounted for by its regression against all predictor variables,	.57	.56	.66
Acceptance confidence		Confidence that the site activity-indicative variables contribute additional information if added to the regression model for Y containing only the meteorological ones	.98	.50	.60

1 Meteorological predictor variables are PREC1, PREC2, HRS3SW, HRS3NE, WS3DAY, INSOL, WS2 and TEMP2

2 Site activity indicators are WRKRS and WKDYND

variation only for the Site 1 data. The final multiple regression coefficients, which were fairly equal at the three sites, still leave at least one-third of the total variation unexplained.

Another approach to regression analysis is to use a technique known as stepwise multiple regression, in which the meteorological and activity indicators are selected in order of decreasing significance as predictors of the dependent variable (particulate concentration). The end result is a ranking and quantitative estimate of the importance of the predictors, regardless of their classification as a meteorological or site activity variable. Table 2-9 presents the results of the stepwise regression for Sites 1, 2 and 3. For each step in each of the regressions, the table lists the predictor entered, the coefficient of multiple regression (R^2) for the regression containing the predictors entered thus far, the increase in this coefficient from the preceeding step, and the standard error of estimate for the regression containing the predictors entered thus far. Predictors added to each regression are included in the table up to the step in which the standard error of the estimate for the regression attains a minimum value.

Examination of the values presented in Table 2-10 reveals the following:

- 24-hour average temperature (from Site 2) is the most significant single predictor of the particulate concentrations at each of the three sites. 45 percent of the variation in the concentration data for Site 3 is explained by the temperature. The corresponding percentages for Site 1 and 2 are, respectively, 23 and 30 percent. In developing a physical explanation for the significance of this parameter in determining particulate concentrations, this factor is considered an indicator of other phenomena acting onsite rather than as the primary cause of the high particulates. That is, the average daily temperature is a seasonal indicator, showing that the particulate concentrations increase as the days warm and the soil becomes drier and more susceptible to wind erosion.

TABLE 2-10. RESULTS OF STEPWISE REGRESSIONS OF PARTICULATE CONCENTRATIONS FOR SITES 1, 2 AND 3

Site 1 Data (41 cases, Std. Dev. 11.3)

Step	1	2	3	4	5	6	7	8
Predictor	TEMP2	WKDYND	WRKRS	PREC1	PREC2	HRS3SW	WS3DAY	INSOL
R^2	.226	.332	.380	.423	.472	.487	.528	.566
Increase in R^2	.226	.106	.048	.043	.049	.015	.041	.038
Standard Error of Estimate	10.1	9.46	9.24	9.03	8.76	8.76	8.54	8.31

Site 2 Data (42 cases, Std. Dev. 11.0)

Step	1	2	3	4	5	6
Predictor	TEMP2	WS3DAY	HRS3SW	HRS3NE	PREC1	PREC2
R^2	.301	.343	.432	.481	.505	.528
Increase in R^2	.301	.042	.089	.049	.024	.023
Standard Error of Estimate	9.33	9.16	8.63	8.37	8.28	8.20

Site 3 Data (39 cases, Std. Dev. 43.6)

Step	1	2	3	4	5	6
Predictor	TEMP2	WS2	WRKRS	INSOL	PREC2	PREC1
R^2	.451	.568	.616	.634	.648	.660
Increase in R^2	.451	.117	.048	.018	.014	.012
Standard Error of Estimate	32.7	29.4	28.2	27.9	27.8	27.7

Correlations among predictors in all three data sets are highest for

WS2 vs WS3DAY ($r > .9$)
WRKRS vs WKDYND and PREC2 vs PREC1 ($.9 > r > .8$)
WS3DAY vs HRS3SW, WS2 vs HRS3SW and HRS3NE vs HRS3SW ($.8 > r > .7$)

- Wind speed is the second most significant predictor of the particulate concentrations at Sites 2 and 3, and minor at Site 1. For the Site 3 data, regression against both the 24-hour average temperature and the Site 2 24-hour average wind speed accounts for 57 percent of the total variation in the concentration data. For the Site 2 data, however, regression against both the temperature and the Site 3 daytime average wind speed accounts for only 34 percent of the total variation in the concentration data. The fact that the stepwise regression for the Site 3 data selected the Site 2 wind speed parameter as a significant predictor, and vice versa, is not significant since there is a high correlation between the two wind speed parameters and a small differences in their F values in the regression steps where one or the other was chosen.

- The combined effect of the two wind speed parameters and the two measures of precipitation could explain no more than 0.15 of the variation in the particulate concentrations at any of the sites, although it might intuitively be expected that these would be important predictors.

- Site activity indicators also explain a maximum of 0.15 of the total variation in the particulate concentrations at any of the sites. The stepwise regression analysis shows the same results as the multiple regression, that is, the activity predictors are more significant at Site 1 than at Site 3.

Conclusions

The following conclusions can be drawn from this analysis:

There is a significant difference in the particulate concentrations during periods with and without snow cover. Since virtually all of the higher concentrations occur during periods without snow cover, most of the analysis was focused on these periods.

Particulate concentrations measured at Sites 1 and 2 are very highly correlated. The difference in trend in the particulate concentrations at

Site 1 from Site 2 is probably explained by the effect of tract activity on Site 1, since Site 1 is closer to the construction area and is at times downwind from the construction area. This influence was shown by both multiple and stepwise multiple regressions.

The meteorological parameters were most effective in predicting particulate concentrations at Site 3 while site activity predictors were surprisingly unimportant. One reason for this is that the activity predictors chosen, because of their availability, may not have been as physically important as the number of heavy construction vehicles in operation or the amount of cleared, exposed ground. Comparison with the baseline data reinforces the conclusion that site meteorology has a large influence on the particulate concentration at Site 3, since higher annual means were measured at Site 3 relative to Sites 1 and 2 during the baseline as well as during the current MDP period. In addition, the maximum concentrations monitored at Site 3 during the baseline period have exceeded those monitored during the MDP period.

Even though meteorology appears to be the controlling influence at Site 3, the regressions do show a minor effect due to site activity. This is substantiated by the increase in mean annual concentrations at Site 3 since the baseline period. In addition, scatter diagrams show that the Site 3/Site 2 and Site 3/Site 1 particulate concentration ratios generally are high during dry weekdays and low during weekdays with precipitation or on weekends. There has also been an increase in mean annual concentrations at Sites 1 and 2, but this may not be significant due to the relatively small sample size and high variability of the data.

The most important parameter in the regression at each site is the 24-hour average temperature. However, this is an example of an easily measured parameter indicating the effects of other physical processes, that is, the particulate concentrations are likely to be higher during the warm, dry summer and fall periods.

At least one-third of the total variability in particulate concentrations at each site is still unexplained. This unexplained variation may be due partly to other parameters that have not been included or to the effects of 24-hour averaging. It is not uncommon in an analysis of particulate data to have some unexplained variation persist.

2.2 METEOROLOGY

Meteorological parameters are monitored to provide information on the general climate of the Rio Blanco Oil Shale Company (RBOSC) Tract C-a and to provide a basis for estimating the potential impact of emissions that will result from tract development and operation. Three meteorological sites have been in operation since the first quarter of the Modular Development Phase (MDP). Site 1, the main sampling site, is at an elevation of 7,380 feet above mean sea level (MSL) just west of the tract boundary. Site 2 is at an elevation of 7,360 ft MSL to the southwest of the tract. Site 3 is located just east of the tract boundary in a broad gulch, at an elevation of 6,580 ft MSL. The terrain in the immediate vicinity of Site 1 slopes gently downward to the northeast, while further away to the northeast, east, and southeast there are many deep ravines or gulches which cut the general level of the plateau 200 feet or more. A topographic map showing the locations of the three sites for the MDP program has been presented (Figure 2-1). This report deals primarily with the meteorological data collected from the three sites during the MDP period December 1977-November 1978 (hereafter referred to as the current year), presented in Appendix 2-2. The data for the baseline period February 1975-January 1977 was extracted as it appeared in the Baseline Report for comparative purposes.

A. Temperature and Stability

1. Objectives

Ambient air temperature, a primary climatic parameter, provides basic information on monthly and year-to-year variability of climatic conditions at the C-a tract. The measured vertical temperature differential within the lowest layers of the atmosphere can be utilized to determine the stability of the atmosphere. The stability has a profound effect on the dispersion of emissions into the atmosphere that may occur as a result of tract development and operation. A further discussion of atmospheric stability at the study area is provided at the end of this section.

2. Methods

Ambient air temperature is measured at the 10-m level at each of the three monitoring locations surrounding the C-a tract. The Site 1 location additionally measures the temperature differential, ΔT, between the 10- and 60-m levels.

3. Results and Discussions

Table 2-11 presents a summary of monthly, seasonal and annual temperature statistics for the current year for each of the three monitoring sites on the tract (10-m level). The temperature statistics presented for each site include means, average daily maximums, average daily minimums, absolute maximums, and absolute minimums.

The monthly mean temperatures for the three sites are very similar with Site 3 generally slightly lower during the fall and winter months. The mean annual temperatures were $7.6^{o}C$ at Site 1, $7.9^{o}C$ at Site 2, and $6.7^{o}C$ at Site 3.

Absolute maximum temperatures and absolute minimum temperatures at Site 1 and Site 2 were very similar. At Site 3, more extreme absolute maximum and minimum temperatures than at Site 1 and Site 2 were the rule for every month. The highest onsite temperature of $32.4^{o}C$ occurred in July at Site 3, and the lowest onsite temperature of $-23.1^{o}C$ occurred in January at Site 3. Similarly, the average daily maximum and minimum temperatures at Site 3 were more extreme than those at Site 1 and Site 2.

The greater temperature range at Site 3 may be explained by examining the differences in site topography. Typically, evening and late night conditions in the area are characterized by clear skies and light winds, resulting in strong radiational cooling at the higher elevations and subsequent drainage of the cold, dense air to lower elevations via the extensive gulch network. Site 3, situated in a valley, receives this cold air drainage flow from the higher elevations to the west. Sites 1 and 2 are on locally high terrain so that the cold air drains away. These downvalley drainage flows can be seen in the meteorological data at

TABLE 2-11. MONTHLY, SEASONAL AND ANNUAL SUMMARY OF TEMPERATURES (^{o}C) (MEAN, AVERAGE DAILY MAXIMUM, AVERAGE DAILY MINIMUM, ABSOLUTE MAXIMUM, ABSOLUTE MINIMUM) FOR THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978 AT THE 10-m LEVEL OF SITE 1, SITE 2 AND SITE 3, RBOSC

	Site 1					Site 2					Site 3				
Monthly	Mean	Avg.* Daily Max	Avg.* Daily Min	Abs Max	Abs Min	Mean	Avg.* Daily Max	Avg.* Daily Min	Abs Max	Abs Min	Mean	Avg.* Daily Max	Avg.* Daily Min	Abs Max	Abs Min
December 1977	-1.9	0.9	-4.9	7.2	-13.9	-1.5	2.0	-5.0	9.9	-15.6	-2.4	4.1	-9.3	12.1	-22.6
January 1978	-3.1	-0.4	-5.5	3.9	-14.2	-2.6	0.7	-5.4	5.6	-16.1	-3.9	2.0	-9.7	6.5	-23.1
February 1978	-2.6	0.4	-5.2	7.2	-12.9	-2.0	1.6	-5.2	7.5	-14.5	-3.2	3.1	-9.0	9	-21
March 1978	2.6	6.0	-1.0	14.9	-11.4	2.9	6.5	-0.8	15.5	-10.9	2.4	8.5	-3.3	17.9	-13
April 1978	5.0	9.1	1.3	16.2	- 5	5.1	9.4	1.2	16	- 4.8	5.5	11.4	-0.7	18.4	- 5.9
May 1978	8.7	12.6	3.8	22.7	- 3.9	8.7	12.5	3.7	22.4	- 4.2	8.6	14.5	0.9	24.7	- 5.5
June 1978	17.9	22.0	12.4	26.4	1.9	18.2	22.3	12.4	26.7	1.8	17.0	24.1	7.1	28.8	- 1.5
July 1978	21.3	25.9	16.8	30.4	9.4	21.8	26.3	17.1	30.5	8.6	20.4	28.4	11.0	32.4	5.0
August 1978	18.8	23.5	13.6	28.1	2.7	19.0	23.9	13.9	28.4	3.5	17.8	25.7	8.5	30.3	- 1.2
September 1978	14.4	18.9	10.0	27.5	- 2.6	14.6	19.4	9.3	27.6	- 2.5	12.8	21.4	4.2	30.1	- 6.1
October 1978	10.8	15.0	7.0	21.8	- 2.0	11.0	15.6	6.2	22.0	- 2.0	8.0	17.1	-0.7	24.3	- 8.0
November 1978	-1.0	2.4	-3.6	14.9	-14.5	-0.7	2.8	-3.6	15.1	-13.8	-2.9	2.9	-8.4	17.4	-18.0
Seasonal															
Winter (Dec, Jan,Feb)	-2.5	0.3	-5.2	7.2	-14.2	-2.0	1.5	-5.2	9.9	-16.1	-3.2	3.1	-9.4	12.1	-23.1
Spring (Mar, Apr,May)	5.4	9.0	1.2	22.7	-11.4	5.6	9.4	1.3	22.4	-10.9	5.5	11.4	-1.1	24.7	-13.0
Summer, (Jun, Jul,Aug)	19.3	23.8	14.3	30.4	1.9	19.7	24.2	14.5	30.5	1.8	18.4	26.1	8.9	32.4	- 1.5
Fall (Sept, Oct,Nov)	8.1	12.5	4.8	27.5	-14.5	8.3	12.8	4.1	27.6	-13.8	6.0	14.0	-1.5	30.1	-18.0
Annual	7.6	11.4	3.8	30.4	-14.5	7.9	12.2	3.9	30.5	-16.1	6.7	13.9	-0.6	32.4	-23.1

* May include rounding errors

Site 3. Due to this local circulation, Site 3 exhibits the coldest temperatures of the three sites by sunrise. During the daytime, Site 3 reaches warmer maximum temperatures than Site 1 or Site 2 because of its lower elevation.

The temperature record also provides the length of the frost-free period at each site. This information is helpful in determining the required hardiness and suitability of plants that will be used in revegetation of the tract. During the current year, Sites 1 and 2 had identical frost-free periods of 111 days (May 31-September 19). Site 3, due to the effects of cold air drainage, had a considerably shorter frost-free period of 75 days (June 1-August 15). The data from Sites 1 and 2 are probably more representative of temperatures and frost-free periods over most of the tract.

Table 2-12 provides a comparison summary of annual absolute minimum, absolute maximum and mean values of the air temperature recorded onsite during each of the baseline years and during the current year, as well as the three data periods combined. Mean temperatures in the current year were slightly warmer than the two baseline years at all three sites.

Stability classifications (A-G), based upon temperature differences (ΔT) within a short vertical distance of the surface, are based on those in the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.23 (NRC 1972). The most turbulent and unstable conditions are characterized by A stability, and the least turbulent and most stable conditions are characterized by G stability.

Table 2-13 presents the diurnal distribution of atmospheric stability classes for Site 1 based on data from the current year. The stable classes (E, F, and G) occur primarily during the nighttime hours and the unstable classes (A, B, and C) occur primarily during the daytime hours when maximum solar heating of the ground surface takes place.

Table 2-14 presents the number of occurrences of stability class persistence for each stability class. The longest persistence during the period occurred for class E conditions and lasted 40 hours.

TABLE 2-12. SUMMARY OF ANNUAL AND COMBINED THREE YEAR ONSITE CLIMATOLOGY OF ABSOLUTE MINIMUM, ABSOLUTE MAXIMUM AND MEAN VALUES OF TEMPERATURE (^{0}C) MEASURED ON RBOSC FEBRUARY 1975-JANUARY 1976, FEBRUARY 1976-JANUARY 1977, AND DECEMBER 1977-NOVEMBER 1978

Temperatures*	Feburary 1975-January 1976	February 1976-January 1977	December 1977-November 1978	3-Yr Combined
Site 1 (10m level)				
Absolute Minimum	-21.1	-21.7	-14.5	-21.7
Absolute Maximum	30.1	29.7	30.4	30.4
Mean	6.1	7.2	7.6	7.0
Site 2 (10m level)				
Absolute Minimum	-21.4	-22.2	-16 1	-22.2
Absolute Maximum ,	27.5	29.4	30.5	30.5
Mean	5.5	6.9	7.9	6.8
Site 3 (10m level)				
Absolute Minimum	-28.2	-25.3	-23.1	-28.2
Absolute Maximum	29.0	32.1	32.4	32.4
Mean	4.3	5.7	6.7	5.6

* Minimum and maximum annual temperatures are based on hourly values for each 1-year period

TABLE 2-13. STABILITY CLASS OCCURRENCE BY HOUR OF DAY AT SITE 1 BASED ON THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

	STABILITY INDEX									
PERIOD	A	B	C	D	E	F	G	TOTAL	FG	EFG
JAN	2	4	4	204	439	44	0	697	44	483
FEB	0	3	9	202	342	43	0	599	43	385
MAR	18	6	13	248	375	54	0	703	54	429
APR	42	26	43	172	292	39	0	614	39	331
MAY	88	47	36	158	189	37	3	558	40	229
JUN	122	33	46	112	231	72	0	616	72	303
JUL	145	29	34	98	195	119	2	622	121	316
AUG	160	48	39	125	253	90	1	713	91	344
SEP	114	26	44	159	261	96	5	705	101	362
OCT	43	27	37	108	281	79	1	576	80	361
NOV	8	10	10	172	265	44	1	510	45	310
DEC	0	4	9	206	477	42	0	738	42	519
SPRING	140	79	92	575	856	130	3	1875	133	989
SUMMER	427	107	119	335	679	281	3	1951	284	963
FALL	165	63	91	433	807	219	7	1785	226	1033
WINTER	2	11	22	618	1258	129	0	2034	129	1387
ANNUAL	734	260	324	1955	3600	759	13	7645	772	4372

TABLE 2-14. STABILITY CLASS PERSISTENCE PERIODS AT SITE 1 BASED ON THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

PERSISTENCE PERIODS (HOURS)	STABILITY INDEX									
	A	B	C	D	E	F	G	TOTAL	FG	EFG
1	40	144	226	241	179	156	13	999	150	39
2	34	40	41	169	110	66	0	460	64	26
3	20	9	4	75	81	37	0	226	34	19
4	25	1	1	43	46	18	0	134	18	13
5	20	1	0	24	38	14	0	97	14	16
6	16	0	0	20	35	6	0	77	7	8
7	23	0	0	19	34	5	0	81	6	8
8	8	0	0	19	22	6	0	55	6	9
9	5	0	0	17	29	4	0	55	5	10
10	0	0	0	15	28	4	0	47	5	13
11	0	0	0	3	21	1	0	25	1	26
12	0	0	0	2	18	1	0	21	1	56
13	0	0	0	1	14	0	0	15	0	41
14	0	0	0	0	13	0	0	13	0	43
15	0	0	0	3	12	0	0	15	0	22
16	0	0	0	1	8	0	0	9	0	18
17	0	0	0	0	8	0	0	8	0	20
18	0	0	0	0	0	0	0	0	0	17
19	0	0	0	0	4	0	0	4	0	10
20	0	0	0	1	0	0	0	1	0	2
21 - 25	0	0	0	0	1	0	0	1	0	2
26 - 30	0	0	0	0	1	0	0	1	0	1
31 - 35	0	0	0	0	0	0	0	0	0	0
36 - 40	0	0	0	0	1	0	0	1	0	1
41 - 45	0	0	0	0	0	0	0	0	0	0
46 - 50	0	0	0	0	0	0	0	0	0	0
51 - 55	0	0	0	0	0	0	0	0	0	0
56 - 60	0	0	0	0	0	0	0	0	0	0
GT 60	0	0	0	0	0	0	0	0	0	0
TOTAL	191	195	272	653	703	318	13	2345	311	420
MAXIMUM NO. HOURS	9	5	4	20	40	12	1	40	12	40
PERCENT LEVEL										
50.00	3.1	0.7	0.6	1.5	2.8	1.0	0.5	1.4	1.1	11.4
80.00	5.9	1.3	1.0	3.9	8.6	2.9	0.8	4.6	3.0	14.4
90.00	6.7	1.8	1.5	6.8	11.5	4.7	0.9	7.7	5.0	16.6
99.00	8.6	3.1	2.6	11.7	17.0	9.7	1.0	15.2	9.8	19.9
99.90	9.6	4.8	3.7	19.3	39.3	11.7	1.0	20.7	11.7	39.6

Table 2-15 presents the occurrence of stability classes by month and season for Site 1 based on data from the current year. Unstable (classes A, B and C) conditions occurred predominantly during the summer. The occurrence of stable conditions showed less seasonal dependence.

Appendix 2-2.3 presents annual stability distribution information in the form of joint frequency distributions (JFD's) by stability class of the 10-m level wind speed and wind direction.

B. Dewpoint

1. Objectives

Dewpoint data, collected since late July 1978, is used in the evaluation of potential cooling system alternatives. The data are more directly useable than relative humidity data, which had been collected onsite for the same purposes during the baseline period and from December 1977 to late July 1978. Relative humidity can be determined from concurrent dewpoint and temperature measurements.

2. Methods

Relative humidity was measured with a sensor utilizing a hygroscopic plastic film that was mounted at the 30-m level on the Site 1 tower. The relative humidity measurements were stopped on July 26, 1978 at 1000, and dewpoint measurements began at Site 1 on July 29, 1978, at 1600.

The dewpoint temperature is measured with a direct measuring sensor utilizing a cooled mirror surface and a photoresistive, condensate-detecting optical system. The mirror temperature, which represents the true dewpoint temperature, is measured by a linear thermistor thermometer imbedded in the mirror. For dewpoints below $0^{o}C$, the system tracks the frostpoint and the frostpoint data have been converted to dewpoint data.

TABLE 2-15. OCCURRENCE OF STABILITY CLASSES BY MONTH AND SEASON FOR SITE 1 BASED ON THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

	STABILITY INDEX									
HR. OF DAY	A	B	C	D	E	F	G	TOTAL	FG	EFG
1	3	0	0	23	232	63	1	322	64	296
2	1	1	0	23	230	66	1	322	67	297
3	3	0	1	21	249	47	1	322	48	297
4	1	1	0	20	249	50	1	322	51	300
5	1	2	2	26	239	49	2	321	51	290
6	1	1	0	51	221	46	0	320	46	267
7	0	3	8	103	180	26	0	320	26	206
8	16	11	18	139	120	14	1	319	15	135
9	40	17	35	152	60	16	0	320	16	76
10	70	28	41	133	37	9	0	318	9	46
11	94	31	36	124	23	10	0	318	10	33
12	115	33	24	122	13	9	0	316	9	22
13	124	20	23	124	13	8	0	312	8	21
14	112	24	22	130	15	9	0	312	9	24
15	87	32	29	137	16	7	0	308	7	23
16	53	32	36	141	43	5	0	310	5	48
17	2	20	41	163	90	4	0	320	4	94
18	0	0	4	145	163	12	0	324	12	175
19	1	1	1	44	249	23	2	321	25	274
20	2	1	1	29	228	60	0	321	60	288
21	2	0	1	26	228	62	0	319	62	290
22	1	0	0	29	235	53	1	319	54	289
23	3	2	0	22	232	58	2	319	60	292
24	2	0	1	28	235	53	1	320	54	289
ALL	734	260	324	1955	3600	759	13	7645	772	4372

3. Results and Discussion

Table 2-16 presents a summary of onsite values of dewpoint temperature, relative humidity and absolute humidity for the current year. Comparisons to the baseline years can be made for relative humidity data only. The mean annual relative humidity during the two baseline years was 36 and 31 percent, as compared to 34 percent during the current year.

C. Wind Speed and Wind Direction

1. Objectives

The wind speed and wind direction influence atmospheric dispersion. Measurement of the frequency of occurrence of wind speed and wind direction classes can be used in interpreting air quality data.

2. Methods

Wind speed and direction are measured by instruments at the 10-m and 60-m levels at Site 1, and at the 10-m level at Sites 2 and 3.

3. Results and Discussion

Annual wind roses for each of the three sites for the two baseline years and for the current year are presented for comparative purposes in Figures 2-15 to 2-17.

During the current year, the Site 1 annual 10-m level wind rose shows the prevalent wind direction to be from the west-southwest, with secondary maxima from the south-southwest and from the southwest. The mean wind speeds associated with these directions were 8.9 mph, 9.4 mph and 6.6 mph, respectively. These data compare favorably with the previous two annual wind roses for the 10-m level at Site 1, which also show the prevalent wind direction to be from the west-southwest. The least favored quadrant at Site 1 for wind direction, as well as the lowest annual average wind speeds, was the southeast quadant during all three

TABLE 2-16. SUMMARY OF MONTHLY, SEASONAL AND ANNUAL DEWPOINT, RELATIVE HUMIDITY AND ABSOLUTE HUMIDITY FOR THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978 AT THE RBOSC TRACT C-a, SITE 1

	Dewpoint (^{o}C)(1)			Relative Humidity (%)(1)			Absolute Humidity (gms/m^3)(1)		
Monthly	Mean	Abs Max	Abs Min	Mean	Abs Max	Abs Min	Mean	Abs Max	Abs Min
December 1977	-	-	-	33	72	21	-	-	-
January 1978	-	-	-	38	72	20	-	-	-
February 1978	-	-	-	34	74	18	-	-	-
March 1978	-	-	-	34	74	17	-	-	-
April 1978	-	-	-	28	72	18	-	-	-
May 1978	-	-	-	24	65	16	-	-	-
June 1978	-	-	-	21	90	14	-	-	-
July 1978	0	5	- 3	24	40	19	4	7	4
August 1978	0	11	-14	35	100	19	5	10	2
September 1978	-1	12	-15	39	100	19	4	11	1
October 1978	-7	4	-23	32	93	19	2	6	1
November 1978	-7	1	-15	67	100	21	2	5	1
Seasonal									
Winter (Dec, Jan,Feb)	-	-	-	35	74	18	-	-	-
Spring (Mar, Apr,May)	-	-	-	29	74	16	-	-	-
Summer (Jun, Jul,Aug)(2)	0	11	-14	34	100	14	5	10	2
Fall (Sept, Oct,Nov)	-5	12	-23	45	100	19	3	11	1
Annual									
July 29, 1978-Nov. 30, 1978	-3	12	-23	34(3)	100(3)	14(3)	3	11	1

(1) Relative humidity measured only up to 7/26/78 1000
Dewpoint measurements began 7/29/74 1600

(2) Based on July 29, 1978-August 31, 1978 data period

(3) Based on December 1977-November 1978 data period

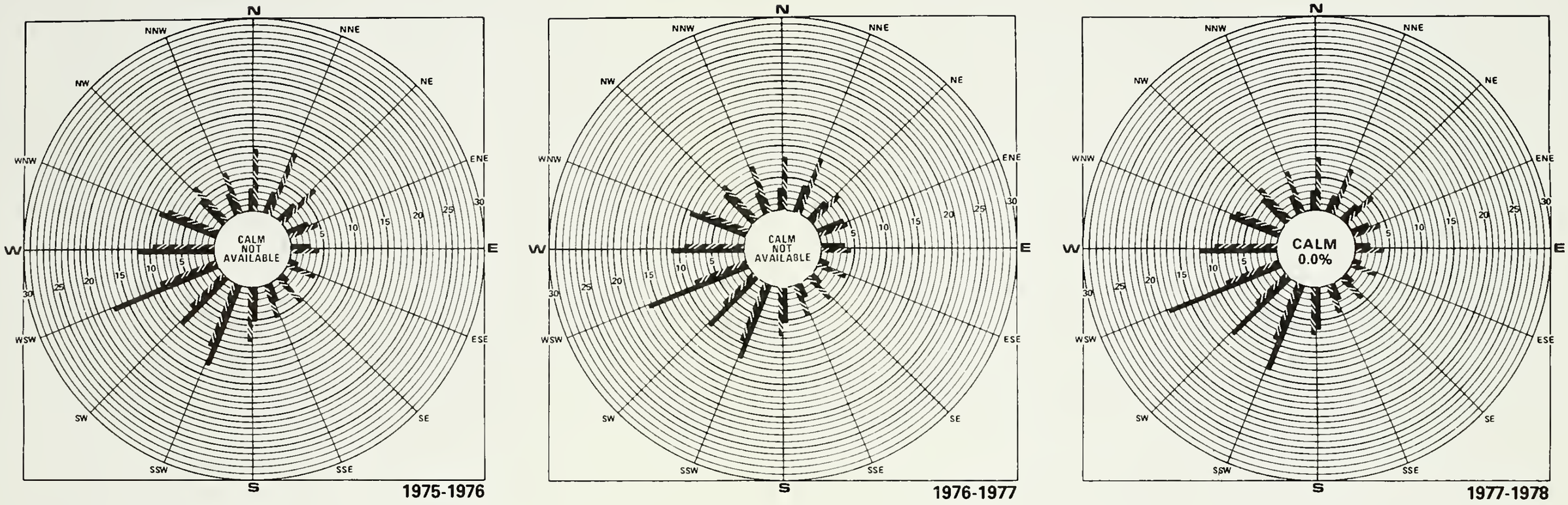


Figure 2-15.

Annual Wind Roses for Tract C-a,
Site 1, 10-m Level for Three Data Periods (February 1975-January 1976, February 1976-January 1977, and December 1977-November 1978).

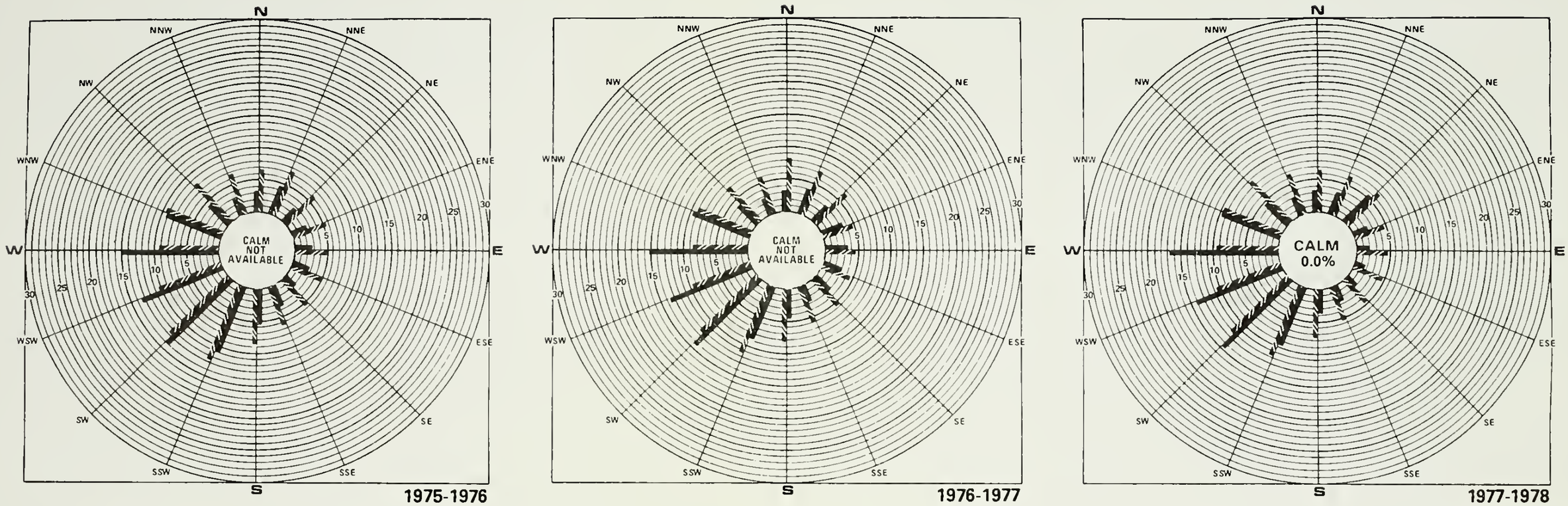


Figure 2-16.

Annual Wind Roses for Tract C-a,
Site 2, 10-m Level for Three Data Periods (February 1975-
January 1976, February 1976-January 1977, and
December 1977-November 1978).

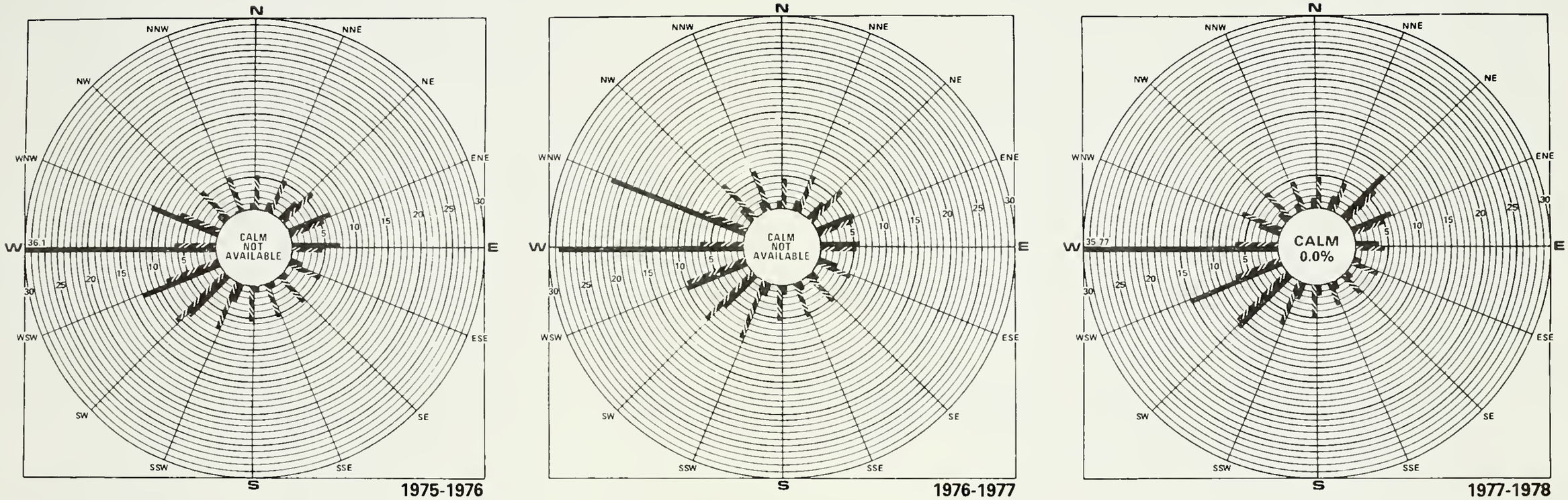


Figure 2-17.

Annual Wind Roses for Tract C-a,
Site 3, 10-m Level for Three Data Periods (February 1975-
January 1976, February 1976-January 1977, and
December 1977-November 1978).

years. The north and the north-northeast were directions of secondary wind speed maxima at Site 1 during the three-year period.

During the current year, the Site 2 annual 10-m level wind rose shows the prevalent wind direction to be from the west, with secondary maxima from the southwest and from the west-southwest. The mean wind speeds associated with these directions were 9.5 mph, 12.2 mph, and 10.6 mph, respectively. These data compare favorably with the two annual wind roses from the baseline period at Site 2, which also show the prevalent wind direction to be from the west. Similar to Site 1, the least favored wind directions and the lowest annual average wind speeds are in the southeast quadrant.

During the current year the Site 3 annual 10-m level wind rose shows the prevalent wind direction, by far, to be from the west (35.8 percent of total annual occurrences), with secondary maxima from the west-southwest and the southwest. The mean wind speeds associated with these directions were 6.5 mph, 7.2 mph, and 10.8 mph, respectively. These data are similar to the two annual wind roses from Site 3 during the baseline period, which also show the prevalent wind direction to be from the west (36.1 and 28.5 percent of the total annual occurrences). This dominance of west winds is due to the combination of the general westerly macroscale circulation and the nighttime drainage wind.

Table 2-17 shows the monthly absolute maximum and mean wind speeds recorded at the 10-m level and 60-m level of Site 1 during the current year. During this period, the mean wind speed was greatest during December at both levels. June and April were months with the next highest mean wind speeds. The highest hourly wind speed recorded at the Site 1 location during the current year was 41.5 mph at the 60-m level in September.

Table 2-18 shows a summary of the absolute maximum and mean hourly wind speeds recorded at each of the three sites during each of the data periods. Detailed information regarding the frequency of occurrence of calm winds at the three sites during the baseline period was not available. The mean wind speeds for the three sites during the current year are 7.6 mph at the Site 1 10-m level, 10.6 mph

TABLE 2-17. SUMMARY OF MONTHLY ABSOLUTE MAXIMUM AND MEAN VALUES OF WIND SPEED FROM (DECEMBER 1977-NOVEMBER 1978) ON TRACT C-a, RBOSC (SITE 1)

Month	Wind Speed (mph) (10m) Absolute Maximum	Wind Speed (mph) (10m) Mean	Wind Speed (mph) (60m) Absolute Maximum	Wind Speed (mph) (60m) Mean
December 1977	30.0	9.6	40.0	14.0
January 1978	23.4	6.0	29.5	8.5
February 1978	20.0	6.0	26.0	8.2
March 1978	18.2	0.5	32.6	9.0
April 1978	24.3	8.8	34.4	13.4
May 1978	27.2	8.3	34.6	11.5
June 1978	22.6	8.9	35.6	13.1
July 1978	23.4	8.1	32.8	10.8
August 1978	19.9	8.3	30.6	11.2
September 1978	27.2	7.7	41.5	10.2
October 1978	22.0	7.1	26.0	8.5
November 1978	21.2	5.7	28.4	7.8

TABLE 2-18. SUMMARY OF ANNUAL ABSOLUTE MAXIMUM AND MEAN VALUES OF WIND SPEED (MPH) DURING THE DATA PERIODS FEBRUARY 1975-JANUARY 1976, FEBRUARY 1976-JANUARY 1977, AND DECEMBER 1977-NOVEMBER 1978 FROM TRACT C-a, RBOSC

	Maximum(1)			Mean			
	1975-1976	1976-1977	1977-1978	1975-1976	1976-1977	1977-1978	3-Yr Combined Mean
Site 1							
10m Wind Speed	30.8	32.3	30.0	7.7	7.2	7.6	7.5
60m Wind Speed	43.0	56.6	41.5	10.6	10.0	10.6	10.4
Site 2							
10m Wind Speed	36.7	39.2	39.0	9.1	8.4	9.2	8.9
Site 3							
10m Wind Speed	29.9	26.4	26.0	6.6	6.9	6.7	6.7

(1) Hourly values for this period

at the Site 1 60-m level, 9.2 mph at Site 2 and 6.7 mph at Site 3. As shown in Table 2-18, there was very little variation in the mean wind speed during the two baseline years from the values obtained during the current year. The decrease in mean wind speeds from Site 2 (highest) to Site 3 (lowest) reflects the relative degree of sheltering by the local terrain.

Tables 2-19 to 2-22 present the 22.5^{o} sector wind direction persistence for the current year for the Site 1 10-m level and 60-m level, the Site 2 10-m level and the Site 3 10-m level. The maximum persistence period was 20 hours from the south for the Site 1 10-m level, 20 hours from the southwest for the Site 1 60-m level, 23 hours from the northeast for the Site 2 10-m level, and 60 hours from the northeast for the Site 3 10-m level.

Tables 2-23 to 2-26 present the annual hourly wind rose (frequency of wind direction occurrences with time of day) for each of the three sites (including the 60-m level at Site 1) during the current year. These tables show the same data as given in the wind rose, but also illustrate the variation throughout the day. Each site shows the dominance of westerly winds. The Site 3 winds show the most extreme case, where winds from the 22.5^{o} west sector occurred more than 60 percent of the time in the early morning hours. These winds are associated with downvalley drainage flows, as discussed earlier.

The most noteworthy event evident in Tables 2-23 to 2-26 is the diurnal variation in the wind direction. It is to be expected that the downvalley wind at Site 3 would reverse and become an upvalley wind shortly after sunrise, due to local solar heating of the terrain. The effect becomes moderately strong and results in an upvalley flow (against the general westerly circulation) approximately 50 percent of the time during the morning hours of 0900 and 1000. Also interesting is the fact that this upvalley flow can be seen, on the average, at each of the three sites. At the 10-m level at Sites 1 and 2 it occurs approximately 25 and 20 percent of the time, respectively. These upslope easterly winds are very uncommon at other times of the day. In addition, this upslope flow appears to be fairly deep, since these easterly winds also occur approximately 20 percent of the time at 0900 on the 60-m level at Site 1.

TABLE 2-19. WIND DIRECTION PERSISTENCE PERIODS FOR 22.5° SECTORS AT THE SITE 1 10m LEVEL DURING THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

PERSISTENCE PERIODS (HOURS)	WIND DIRECTION																	
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	130	131	144	113	105	85	110	158	276	341	448	380	355	264	208	146	2	3396
2	21	16	24	32	14	6	16	20	62	106	137	139	98	73	45	17	2	828
3	6	3	8	6	9	0	2	7	19	41	37	73	37	37	19	8	0	312
4	2	6	2	1	3	0	1	1	8	27	19	29	24	11	6	6	0	146
5	1	4	2	2	0	0	0	0	2	15	6	17	10	5	3	1	0	68
6	1	1	0	0	0	0	0	0	2	10	2	15	3	4	0	0	0	38
7	0	0	0	1	0	0	0	0	0	4	2	7	4	1	0	0	0	19
8	0	0	0	0	0	0	0	0	0	4	0	7	1	2	0	0	0	14
9	1	0	0	0	0	0	0	0	0	2	0	3	1	0	0	0	0	7
10	0	0	0	0	0	0	0	0	0	4	0	4	3	0	0	0	0	11
11	0	0	0	0	0	0	0	0	0	1	0	3	2	0	0	0	0	6
12	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0	4
13	0	0	0	1	0	0	0	0	0	1	0	4	0	0	0	0	0	6
14	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
15	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
16	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAXIMUM NO. HOURS	16	6	5	13	4	2	4	4	20	14	12	16	15	8	5	5	2	20

NUMBER OF OBS = 7845

TABLE 2-20. WIND DIRECTION PERSISTENCE PERIODS FOR 22.5° SECTORS AT THE SITE 1 60m LEVEL DURING THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

PERSISTENCE PERIODS (HOURS)	WIND DIRECTION																	
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	180	158	167	107	103	104	127	194	218	301	355	281	226	188	150	153	2	3014
2	46	37	38	36	21	10	15	32	72	117	126	126	72	35	28	31	0	842
3	12	13	9	6	3	1	6	6	22	51	62	43	30	17	18	13	0	312
4	3	11	1	4	1	0	0	6	8	24	30	17	18	11	5	2	0	141
5	1	1	3	1	0	0	1	2	3	26	22	17	11	5	2	0	0	95
6	3	1	0	0	1	0	0	0	3	9	6	7	3	0	1	0	0	34
7	0	3	1	2	0	0	0	0	2	7	9	8	6	1	0	0	0	39
8	0	1	0	0	0	0	0	0	1	8	5	0	2	0	0	0	0	17
9	0	0	0	0	0	0	0	0	0	5	2	4	1	0	0	0	0	12
10	1	0	0	0	0	0	0	0	0	4	5	1	2	1	0	0	0	14
11	0	1	0	0	0	0	0	0	0	4	3	1	3	0	0	0	0	12
12	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	3
13	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	0	4
14	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	3
15	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
16	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAXIMUM NO. HOURS	20	11	7	7	6	3	5	5	8	16	20	15	14	10	6	4	1	20

NUMBER OF OBS = 7867

TABLE 2-21. WIND DIRECTION PERSISTENCE PERIODS FOR 22.5^{o} SECTORS AT THE SITE 2 10m LEVEL DURING THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

PERSISTENCE PERIODS (HOURS)	WIND DIRECTION																	
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	161	148	133	121	93	94	113	139	187	274	340	342	316	254	193	145	0	3053
2	19	20	31	17	24	12	17	23	31	83	127	132	136	95	37	21	0	825
3	6	10	10	4	1	4	2	4	12	22	38	45	54	28	11	6	0	257
4	3	8	4	2	0	0	1	1	1	17	30	23	50	19	2	4	0	165
5	2	2	6	0	1	0	0	0	1	18	23	10	15	8	3	0	0	89
6	1	0	2	1	0	0	0	1	1	6	4	7	6	3	0	1	0	33
7	1	1	3	0	0	0	0	0	0	0	4	6	6	3	1	0	0	25
8	0	0	0	0	0	0	0	0	0	2	10	0	5	4	1	0	0	22
9	0	0	1	0	0	0	0	0	0	0	2	4	0	1	0	0	0	8
10	0	0	1	0	0	0	0	0	0	0	0	2	2	1	0	0	0	6
11	0	0	1	0	0	0	0	0	0	0	1	1	2	0	0	0	0	5
12	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	3
13	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
14	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
16	0	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4
17	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAXIMUM NO. HOURS	7	7	23	6	5	3	4	6	6	12	12	14	17	10	15	6	0	23

NUMBER OF OBS = 7562

TABLE 2-22. WIND DIRECTION PERSISTENCE PERIODS FOR 22.5° SECTORS AT THE SITE 3 10m LEVEL DURING THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

PERSISTENCE PERIODS (HOURS)	WIND DIRECTION																	
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	87	125	124	205	168	66	61	78	94	124	205	449	273	163	99	78	11	2407
2	12	16	34	64	30	4	5	6	10	17	37	110	126	26	9	5	2	533
3	3	2	13	24	9	2	3	1	4	10	21	53	80	9	3	1	0	238
4	0	0	9	8	6	0	0	0	0	1	15	18	53	2	0	0	0	112
5	0	1	6	5	0	0	0	0	0	0	17	13	42	0	0	0	0	84
6	0	0	3	0	0	0	0	0	0	0	7	12	36	0	0	0	0	58
7	0	0	4	2	0	0	0	0	0	0	9	4	21	0	0	0	0	40
8	0	0	2	1	0	0	0	0	0	0	3	2	17	0	0	0	0	25
9	0	0	2	2	0	0	0	0	0	0	3	0	15	0	0	0	0	22
10	0	0	1	0	0	0	0	0	0	1	4	2	11	0	0	0	0	19
11	0	0	4	0	0	0	0	0	0	0	2	2	21	0	0	0	0	29
12	0	0	0	0	0	0	0	0	0	0	3	0	11	0	0	0	0	14
13	0	0	1	0	0	0	0	0	0	0	2	0	10	0	0	0	0	13
14	0	0	1	0	0	0	0	0	0	0	1	0	5	0	0	0	0	7
15	0	0	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0	6
16	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
17	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
18	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
21	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	3
22	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
MAXIMUM NO. HOURS	3	5	60	9	4	3	3	3	3	10	14	11	21	4	3	3	2	60

NUMBER OF OBS = 7364

TABLE 2-23. ANNUAL HOURLY WIND ROSE (FREQUENCY OF WIND DIRECTION OCCURRENCE WITH TIME OF DAY) FOR THE SITE 1 10m LEVEL, DURING THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

WIND DIRECTION

HR. OF DAY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	2.1	1.2	1.2	0.6	0.3	0.3	1.5	2.7	7.3	7.9	14.2	30.6	12.7	8.8	5.2	3.3	0.0	100.
2	2.7	1.5	0.3	1.5	0.3	0.9	1.5	2.4	4.9	10.6	12.8	23.1	16.7	10.3	6.4	4.0	0.0	100.
3	2.4	2.7	0.9	0.6	0.9	1.5	3.0	3.0	5.8	8.2	14.0	22.0	14.6	10.4	5.5	4.3	0.0	100.
4	2.1	3.3	0.6	0.6	0.9	0.6	1.2	2.1	6.4	9.7	17.6	22.1	12.1	12.7	4.2	3.6	0.0	100.
5	3.4	3.0	1.2	1.5	0.9	0.3	1.5	1.8	5.5	12.2	16.5	21.3	14.0	7.9	7.0	1.5	0.3	100.
6	4.0	3.7	2.4	1.2	2.1	0.6	2.8	2.4	6.4	10.1	15.6	17.7	12.5	10.4	3.7	4.0	0.3	100.
7	4.3	5.5	3.1	4.9	3.7	1.5	3.1	4.9	9.2	12.6	10.5	13.8	10.2	5.2	3.7	3.7	0.0	100.
8	3.7	1.5	6.5	8.9	7.4	2.2	4.6	7.4	10.5	12.0	6.5	13.5	8.3	3.1	1.5	2.2	0.3	100.
9	2.8	2.8	6.7	11.9	6.1	4.0	5.5	5.2	9.8	12.8	7.6	14.4	5.5	3.4	0.9	0.3	0.3	100.
10	4.0	3.0	7.6	10.1	8.5	3.7	3.0	3.4	7.3	14.9	9.8	12.2	6.4	3.7	0.9	1.5	0.0	100.
11	2.1	3.4	5.8	7.3	6.7	1.2	3.4	3.4	8.0	17.7	7.0	16.8	7.3	4.9	2.1	2.8	0.0	100.
12	3.4	2.2	7.1	4.3	2.2	1.2	2.2	0.6	5.9	22.0	9.0	15.2	13.6	3.4	5.9	1.9	0.0	100.
13	2.8	4.3	4.7	2.2	1.9	0.6	1.2	1.9	7.5	19.6	11.5	12.4	14.9	7.8	3.7	3.1	0.0	100.
14	3.4	2.8	3.1	3.7	1.2	0.9	0.3	1.9	8.7	18.1	10.9	13.1	14.3	7.8	5.9	3.7	0.0	100.
15	4.1	2.8	3.2	2.2	1.9	0.3	0.9	1.3	6.6	21.8	12.0	11.4	13.9	7.6	6.9	3.2	0.0	100.
16	4.3	4.3	1.5	2.8	2.5	0.9	0.0	2.2	8.4	20.7	11.1	11.1	9.6	9.3	8.0	3.1	0.0	100.
17	2.8	2.8	2.8	3.1	0.9	1.2	1.8	2.1	7.7	21.8	10.7	10.4	10.1	8.0	8.6	4.9	0.3	100.
18	4.5	3.3	3.6	0.3	0.9	2.4	0.6	2.4	7.5	19.2	12.3	12.3	10.2	8.4	7.8	4.2	0.0	100.
19	3.0	3.6	1.2	0.3	0.9	2.1	1.5	2.1	4.2	17.2	16.6	18.7	9.9	10.8	4.5	3.3	0.0	100.
20	1.5	1.8	1.8	0.6	0.9	1.2	1.2	2.4	6.6	10.8	12.7	27.1	13.3	10.5	5.7	2.4	0.0	100.
21	1.5	2.4	2.1	0.6	0.6	0.3	0.9	3.6	4.3	9.4	14.9	24.9	16.4	7.9	6.4	3.6	0.0	100.
22	1.5	1.8	2.1	0.3	0.3	0.0	1.5	3.0	4.9	11.3	11.9	27.7	15.2	11.0	4.3	2.7	0.3	100.
23	1.2	2.5	0.9	0.0	0.3	0.6	1.2	4.0	5.5	8.6	15.6	25.8	13.2	11.0	7.4	2.1	0.0	100.
24	4.0	1.5	1.8	0.6	0.3	0.9	1.8	1.8	4.0	7.6	17.3	30.1	11.9	10.3	4.3	1.8	0.0	100.
ALL	3.0	2.8	3.0	2.9	2.2	1.2	1.9	2.8	6.8	14.0	12.5	18.7	12.0	8.1	5.0	3.0	0.1	100.

NUMBER OF OBS = 7845

TABLE 2-24. ANNUAL HOURLY WIND ROSE (FREQUENCY OF WIND OCCURRENCE WITH TIME OF DAY) FOR THE SITE 1 60m LEVEL DURING THE DATA PERIOD NOVEMBER 1977-DECEMBER 1978, RBOSC

	WIND DIRECTION																	
HR. OF DAY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	6.7	3.9	1.8	1.8	0.6	1.2	3.3	3.6	6.7	12.1	17.0	17.9	11.2	3.3	3.6	5.2	0.0	100.
2	6.4	6.4	3.0	1.2	1.2	1.5	1.5	5.2	8.2	10.3	17.9	15.8	10.0	3.6	0.9	6.4	0.3	100.
3	6.9	7.9	3.0	1.5	1.2	1.2	3.0	5.7	7.9	10.9	16.1	13.6	10.0	3.6	3.9	4.5	0.0	100.
4	7.0	6.4	3.3	0.6	1.5	0.6	3.3	4.5	10.0	13.6	15.2	12.4	9.1	3.3	4.8	4.2	0.0	100.
5	4.8	4.5	5.2	0.6	2.1	1.2	2.1	3.6	9.4	13.6	13.9	15.5	10.6	2.7	3.9	6.1	0.0	100.
6	6.4	8.5	3.3	2.1	0.6	2.1	1.2	6.7	7.6	12.8	16.4	10.9	10.6	4.0	3.3	3.0	0.3	100.
7	6.4	7.0	2.7	2.7	3.4	2.7	4.3	6.1	8.2	12.2	17.1	9.5	8.8	3.0	2.1	3.7	0.0	100.
8	4.6	3.0	6.1	7.3	5.5	4.0	6.5	7.0	8.8	14.6	14.3	10.7	5.5	1.8	0.3	0.9	0.0	100.
9	1.5	3.3	4.5	10.9	7.6	3.0	3.9	8.5	7.9	14.8	14.2	11.2	5.2	2.1	0.6	0.6	0.0	100.
10	2.7	2.7	6.4	9.1	6.1	3.7	4.0	4.9	5.5	17.1	14.6	11.6	6.1	2.7	1.8	0.9	0.0	100.
11	1.8	3.4	5.5	7.0	5.5	1.5	2.8	3.1	4.9	20.2	13.1	15.6	7.3	3.7	2.1	2.4	0.0	100.
12	3.7	2.5	6.2	4.6	2.8	0.9	1.2	1.5	2.2	20.7	17.0	15.4	11.7	2.8	4.3	2.5	0.0	100.
13	3.1	3.4	4.3	2.8	1.2	0.9	0.9	1.2	3.7	19.5	17.3	13.3	15.8	6.2	2.5	3.7	0.0	100.
14	4.0	3.1	4.0	2.2	1.2	0.9	0.3	1.2	3.1	18.3	21.4	12.1	13.0	8.1	3.7	3.1	0.0	100.
15	2.5	3.2	2.2	3.2	1.6	1.3	0.6	1.3	1.3	20.5	19.9	12.0	12.9	8.2	5.7	3.8	0.0	100.
16	4.6	4.0	1.5	2.2	1.9	0.6	1.2	1.2	3.1	22.0	18.3	10.2	10.2	9.0	7.7	2.2	0.0	100.
17	4.0	2.1	3.7	2.1	1.2	0.9	0.9	2.1	4.3	22.4	16.0	7.4	11.7	9.8	6.7	4.6	0.0	100.
18	4.5	3.9	6.0	0.6	0.6	1.2	1.5	3.6	5.1	20.1	16.8	7.5	8.7	7.8	7.8	4.2	0.0	100.
19	4.8	5.1	2.1	1.8	0.9	1.8	1.8	3.9	6.3	16.6	22.6	8.1	7.2	8.7	4.2	3.9	0.0	100.
20	4.8	6.3	1.5	2.4	0.3	1.5	1.8	4.5	6.9	15.7	20.2	12.1	9.4	6.3	4.2	1.8	0.0	100.
21	4.5	4.8	3.9	1.2	0.6	1.5	2.1	4.2	7.6	11.8	20.9	13.3	8.8	6.7	4.5	3.3	0.0	100.
22	4.2	3.9	3.0	1.8	0.6	1.5	3.0	4.5	7.6	14.2	19.4	14.2	8.8	5.5	4.5	3.0	0.0	100.
23	7.0	5.5	3.0	0.9	0.3	1.5	2.4	3.0	11.9	12.2	16.5	14.0	11.6	3.4	4.0	2.7	0.0	100.
24	6.4	6.4	3.7	0.0	1.5	1.2	1.8	2.7	8.5	12.2	15.9	20.1	9.5	4.3	2.7	3.0	0.0	100.
ALL	4.7	4.7	3.8	2.9	2.1	1.6	2.3	3.9	6.5	15.7	17.1	12.7	9.7	5.0	3.8	3.3	0.0	100.

NUMBER OF OBS = 7867

TABLE 2-25. ANNUAL HOURLY WIND ROSE (FREQUENCY OF WIND OCCURRENCE WITH TIME OF DAY) FOR THE SITE 2 10m LEVEL DURING THE DATA PERIOD NOVEMBER 1977-DECEMBER 1978, RBOSC

WIND DIRECTION

HR. OF DAY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	3.1	2.5	3.8	0.6	0.0	0.3	1.9	2.5	5.0	8.2	11.6	16.7	21.7	12.3	6.0	3.8	0.0	100.
2	3.8	2.5	2.8	1.3	0.3	0.9	3.1	3.1	5.0	9.7	11.6	16.3	21.9	10.7	4.1	2.8	0.0	100.
3	3.1	3.8	3.4	1.3	0.6	0.0	3.8	3.8	5.0	8.2	10.3	15.0	23.8	10.3	3.4	4.1	0.0	100.
4	4.1	2.5	3.5	1.6	0.6	0.9	1.6	4.4	2.5	8.8	11.9	15.7	23.0	10.1	6.9	1.9	0.0	100.
5	4.4	3.8	3.8	1.9	0.3	1.6	2.5	1.9	3.8	10.7	11.7	15.8	22.1	9.5	3.2	3.2	0.0	100.
6	4.7	3.5	4.1	1.6	1.3	1.3	2.5	4.1	4.4	9.2	12.7	14.2	20.9	7.9	4.4	3.2	0.0	100.
7	5.1	4.4	5.4	3.8	1.6	3.8	2.2	4.1	5.4	8.9	10.1	13.6	13.9	8.9	6.3	2.5	0.0	100.
8	5.4	5.7	6.6	3.8	5.7	4.4	6.3	4.1	6.9	8.2	10.1	13.6	10.7	3.5	2.8	2.2	0.0	100.
9	2.5	3.1	5.3	6.3	8.8	10.1	4.1	3.1	5.3	9.7	12.9	14.5	7.9	2.8	1.9	1.6	0.0	100.
10	1.9	3.5	6.7	7.6	6.7	5.4	6.1	3.8	2.2	9.6	16.6	11.1	10.2	4.8	2.2	1.6	0.0	100.
11	3.8	5.1	9.0	4.2	3.8	1.0	1.6	2.9	2.2	10.9	16.0	11.2	18.6	4.2	3.8	1.6	0.0	100.
12	3.9	4.2	7.4	3.9	3.2	1.0	0.6	0.6	1.9	11.6	15.8	12.3	20.0	6.8	3.5	3.2	0.0	100.
13	2.8	3.6	8.7	1.6	1.6	1.9	0.3	1.0	2.3	9.4	18.8	12.6	15.5	12.6	3.9	3.6	0.0	100.
14	2.6	6.2	6.9	2.3	1.6	0.3	0.3	0.0	2.9	10.5	17.6	14.1	15.4	11.8	4.2	3.3	0.0	100.
15	3.6	2.9	7.2	2.6	1.0	0.0	0.7	0.7	2.3	12.4	15.3	15.0	14.7	12.7	6.2	2.9	0.0	100.
16	3.9	3.2	6.8	3.2	1.3	0.3	0.0	1.6	3.2	12.3	17.2	11.0	11.0	15.2	8.1	1.9	0.0	100.
17	4.2	3.8	7.3	2.2	1.3	1.0	1.0	2.2	3.2	10.5	20.1	10.5	7.3	15.7	6.7	2.9	0.0	100.
18	3.7	2.8	8.4	2.2	1.9	1.2	1.6	3.1	4.7	9.7	17.4	11.2	9.3	11.2	6.5	5.0	0.0	100.
19	1.6	4.4	5.0	1.6	1.9	1.6	2.2	3.8	3.1	9.1	20.4	11.3	12.9	11.6	6.3	3.4	0.0	100.
20	2.2	3.1	5.0	0.9	0.9	0.9	1.6	3.1	4.1	9.7	17.6	15.0	17.6	11.0	4.4	2.8	0.0	100.
21	2.2	2.8	4.1	0.6	0.9	1.3	2.5	2.5	4.7	7.9	16.4	17.4	19.2	9.8	4.4	3.2	0.0	100.
22	2.2	2.5	5.1	0.6	0.9	0.6	0.9	2.5	4.4	9.8	16.5	15.5	20.3	10.4	3.8	3.8	0.0	100.
23	4.1	2.9	4.4	1.3	0.6	0.6	1.3	3.8	6.0	7.0	12.1	20.0	20.0	9.2	4.8	1.9	0.0	100.
24	1.3	1.9	4.7	0.6	0.3	0.6	0.9	2.5	4.1	9.5	13.9	17.0	22.4	10.4	4.1	5.7	0.0	100.
ALL	3.3	3.5	5.6	2.4	2.0	1.7	2.1	2.7	4.0	9.6	14.8	14.2	16.7	9.7	4.7	3.0	0.0	100.

NUMBER OF OBS = 7562

TABLE 2-26. ANNUAL HOURLY WIND ROSE (FREQUENCY OF WIND DIRECTION OCCURRENCE WITH TIME OF DAY) FOR THE SITE 3 10m LEVEL DURING THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

	WIND DIRECTION																	
HR. OF DAY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	1.0	1.0	7.8	2.9	2.3	0.0	1.3	0.3	1.6	1.3	4.2	14.3	57.7	3.9	0.3	0.0	0.0	100.
2	1.0	1.3	7.4	1.6	1.0	0.3	1.3	1.0	0.3	1.9	2.9	14.2	61.6	1.9	1.9	0.0	0.3	100.
3	0.3	2.6	5.8	1.6	2.3	1.0	0.3	1.0	1.0	1.3	2.6	15.6	60.1	2.6	1.0	0.3	0.6	100.
4	0.3	0.7	6.2	2.3	1.3	0.7	1.0	1.0	1.0	0.7	2.6	13.7	63.5	1.0	2.6	1.0	0.7	100.
5	1.3	0.6	6.8	2.6	1.6	0.3	0.0	0.6	1.0	1.6	4.2	11.3	63.4	3.6	2.3	1.0	0.6	100.
6	1.0	1.0	7.8	1.6	1.3	1.0	1.0	1.3	0.3	1.3	3.3	11.4	58.2	5.9	2.6	0.7	0.3	100.
7	2.3	4.9	8.7	6.1	4.2	1.3	1.9	1.6	2.9	2.6	5.5	17.5	31.1	4.2	2.9	1.9	0.3	100.
8	2.3	3.2	10.4	13.9	9.1	5.2	3.9	4.2	3.2	3.2	9.4	11.3	15.9	3.9	1.0	1.6	0.6	100.
9	1.3	4.5	11.6	21.6	12.9	2.3	1.6	3.2	3.2	2.6	11.0	13.5	6.8	1.3	1.3	1.3	0.0	100.
10	2.3	2.0	12.7	20.5	13.0	3.3	2.9	1.3	2.9	4.6	14.7	11.1	5.5	2.0	0.3	1.0	0.0	100.
11	2.6	1.7	12.5	16.8	9.2	2.3	1.7	0.3	1.7	4.6	20.1	13.5	9.6	1.0	1.3	1.0	0.0	100.
12	2.3	2.3	12.2	10.9	6.6	2.0	1.3	1.0	1.6	3.3	24.7	14.5	11.2	3.3	2.0	1.0	0.0	100.
13	2.6	3.0	10.9	10.3	3.6	0.7	1.0	1.3	0.3	3.3	25.8	13.2	18.2	2.6	2.3	0.7	0.0	100.
14	1.3	3.3	11.7	8.0	3.3	0.3	0.7	0.0	0.7	4.7	23.4	16.7	16.4	4.7	2.0	2.7	0.0	100.
15	2.3	2.3	11.3	10.0	1.7	0.3	0.0	0.3	1.7	4.0	24.6	16.3	15.9	5.3	3.0	1.0	0.0	100.
16	3.6	4.3	9.3	7.3	2.3	0.0	0.0	2.0	2.0	5.0	23.5	15.2	15.2	6.3	2.0	2.0	0.0	100.
17	2.3	4.0	9.9	5.9	3.6	1.3	1.3	1.0	2.6	3.6	21.8	14.5	15.2	8.3	3.3	1.3	0.0	100.
18	2.9	3.8	7.3	4.8	2.9	0.6	1.3	1.3	3.2	4.5	16.9	17.8	20.1	7.0	1.9	3.5	0.3	100.
19	1.3	3.8	7.0	4.2	1.9	1.3	1.3	1.6	2.2	2.6	10.2	23.0	33.2	3.5	1.6	1.3	0.0	100.
20	0.6	1.6	6.4	4.2	1.9	1.0	0.3	2.3	1.3	1.9	3.5	19.0	51.1	2.9	0.6	1.0	0.3	100.
21	0.6	1.3	7.4	1.6	1.9	0.6	0.0	2.3	1.3	1.9	4.9	13.3	57.3	2.3	1.6	1.0	0.6	100.
22	1.9	1.0	7.8	1.6	0.6	0.0	0.3	1.0	1.3	2.6	2.9	17.5	57.8	1.9	0.3	1.3	0.0	100.
23	1.3	0.0	8.2	2.0	0.7	0.3	0.7	0.0	1.6	1.6	2.9	20.9	55.6	2.0	1.3	1.0	0.0	100.
24	0.3	0.7	7.8	1.6	1.6	0.0	1.0	0.3	2.0	1.3	3.6	16.3	55.0	4.6	1.6	2.3	0.0	100.
ALL	1.6	2.3	8.9	6.8	3.8	1.1	1.1	1.3	1.7	2.7	11.1	15.2	35.7	3.4	1.7	1.2	0.2	100.

NUMBER OF OBS = 7364

This result may partly explain the importance of site activity predictors on the Site 1 particulate concentrations found in the regression analysis. That is, during mid-morning hours on some days, Site 1, rather than Site 3, is downwind of the construction area. This effect may also be important for the pollutants when the retorts begin operation.

D. Precipitation

1. Objectives

Precipitation is recorded to provide data on the scavenging effects of rain and snowfall on air quality. The moisture content of the ground surface may also influence wind erosion.

2. Methods

The methods followed for collection of these data were described in RBOSC MDP Report 2 and are not repeated herein.

3. Results and Discussion

Precipitation data from the several measuring methods for the period June 1978-November 1978 are included in the data appendix (Appendix 2-2.4). There is a signficant difference in the reported precipitation between the gauges installed at each site, with the weighing bucket gauges in general recording relatively higher precipitation amounts than the tipping bucket gauges.

Table 2-27 presents the monthly, seasonal and annual precipitation amounts (inches) at Sites 1, 2 and 3 from available tipping bucket gauge data during the two baseline years. The table also includes the current year precipitation data for all three sites as measured by the tipping bucket gauges, weighing bucket gauges and wedge gauges. The current year was the wettest of the three years at all three sites with an annual total of 9.57 to 11.37 inches measured at each gauge with a full record. During this year, the highest precipitation amounts

TABLE 2-27. MONTHLY, SEASONAL AND ANNUAL PRECIPITATION AMOUNTS (INCHES) AT SITES 1, 2 AND 3 FROM AVAILABLE TIPPING BUCKET GAUGE, WEIGHING BUCKET GAUGE AND WEDGE GAUGE DATA DURING THE THREE ANNUAL DATA PERIODS FEBRUARY 1975-JANUARY 1976, FEBRUARY 1976-JANUARY 1977 AND DECEMBER 1977-NOVEMBER 1978 AT RBOSC TRACT C-a

Month	Tipping Bucket Gauge February 1975-January 1976				Tipping Bucket Gauge February 1976-January 1977				A=Tipping Bucket B=Weighing Bucket C=Wedge Gauge December 1977-November 1978											
	Site 1	Site 2	Site 3	Avg(1)	Site 1	Site 2	Site 3	Avg(1)	Site 1			Site 2			Site(3) 3		Avg(1)			
									A	B	C	A	B	C	A	C	A	B	C
December	0.01	0.01	0.41	0.14	0.01	0.10	0.06	0.06	-	0.91	0.35	-	0.56	0.29	-	0.56	-	0.74	0.40
January	0.01	0.00	0.06	0.02	0.05	0.36	0.39	0.27	-	1.47	1.18	-	1.06	0.75	-	0.73	-	1.27	0.89
February	0.01	0.04	0.05	0.03	0.57	0.02	0.46	0.35	-	0.95	0.75	-	1.21	0.52	-	0.41	-	1.08	0.56
March	0.12	0.01	0.15	0.09	0.44	0.09	0.63	0.39	-	2.36	1.99	-	2.11	1.86	1.24	2.02	1.24	2.24	1.96
April	0.14	0.07	0.28	0.16	0.50	0.42	0.30	0.41	1.04	1.74	1.56	1.02	1.47	1.27	1.12	1.00	1.06	1.24	1.28
May	0.13	0.12	0.68	0.31	0.93	1.41	1.40	1.25	0.36	1.05	0.72	1.38(2)	1.61(2)	1.50	0.97	0.96	0.90	1.33	1.06
June	0.05	0.03	0.12	0.07	1.48	1.54	1.08	1.37	-(2)	-	0.81	0.26(2)	0.19(2)	0.25	0.81	0.83	0.54	-	0.63
July	0.04	0.03	0.08	0.05	0.80	1.02	0.83	0.88	0.25(2)	0.37	0.44	0.40	0.35(2)	0.39	0.35	0.30	0.33	0.36	0.38
August	0.02	0.00	0.13	0.05	0.51(2)	0.98	0.61	0.70	0.35	0.53	0.57	0.63	0.60(2)	0.57	0.42	0.44	0.47	0.53	0.53
September	0.01	0.18	0.13	0.11	0.29(2)	NA(2)	0.73	0.73	0.45	0.76	0.68	0.55	0.26(2)	0.57	0.31	0.45	0.44	0.76	0.57
October	0.06	0.24	0.49	0.26	0.22	0.01(2)	0.26	0.24	0.15	0.23	0.20	0.23	0.27	0.28	-	0.20	0.19	0.25	0.23
November	0.05	0.01	0.41	0.16	0.00	0.02	0.00	0.01	1.03	2.22	2.06	1.10	1.68	1.85	0.30(2)	1.67	1.07	1.95	1.86
Seasonal																			
Winter (Dec, Jan,Feb)	0.03	0.05	0.52	0.20	0.63	0.48	0.91	0.67	-	3.33	2.28	-	2.83	1.56	-	1.70	-	3.08	1.85
Spring (Mar, Apr,May)	0.39	0.20	1.11	0.57	1.87	1.92	2.33	2.04	-	5.15	4.27	-	5.19	4.63	3.33	3.98	3.33	5.17	4.29
Summer (Jun, Jul,Aug)	0.11	0.06	0.33	0.17	2.79	3.54	2.52	2.95	-	-	1.82	1.29(2)	1.14(2)	1.21	1.58	1.57	1.58	-	1.53
Fall (Sept, Oct,Nov)	0.12	0.43	0.93	0.49	0.51(2)	0.03(2)	0.99	0.99	1.63	3.21	2.94	1.88	2.21(2)	2.70	-	2.32	1.76	3.21	2.65
Annual	0.65	0.74	2.89	1.43	5.80(2)	5.97(2)	6.75	6.65(2)	-	-	11.31	-	11.37(2)	10.10	-	9.57	-	-	10.32

(1) Average is based upon sites with complete data only
(2) Partial data only
(3) Site 3 does not have a Weighing Bucket Gauge
- Data not available

were recorded during March and November, with the latter month including unusually heavy amounts of snow. The driest month was October. The variability between sites and precipitation gauges evident in Table 2-27 is attributed to natural variability of precipitation in the semi-arid climate of the region, the complexity of orographic influences in the region, and the different exposure and capture efficiencies of the precipitation gauges.

E. Solar Insolation

1. Objective

Solar insolation is monitored to acquire a data base useful in interpreting air quality data.

2. Methods

Insolation is measured with a pyranometer mounted at ground level at Site 1.

3. Results and Discussion

Table 2-28 compares the onsite values of maximum and mean solar insolation data obtained from Site 1 for the two baseline years and the current year. The annual mean solar insolation for each of the three data periods was 0.3 langleys/min, equivalent to 432 langleys/day.

TABLE 2-28. THREE-YEAR MAXIMUM AND MEAN SOLAR INSOLATION DATA AT SITE 1 FOR DATA PERIODS FEBRUARY 1975-JANUARY 1976, FEBRUARY 1976-JANUARY 1977 AND DECEMBER 1977-NOVEMBER 1978, RBOSC TRACT C-a

Month	Solar Insolation (Langleys/Min) at Site 1						Three-Year Mean Solar Insolation
	1975-1976 Feb-Jan		1976-1977 Feb-Jan		1977-1978 Dec-Nov		
	Maximum	Mean	Maximum	Mean	Maximum	Mean	
January	0.8	0.2	0.9	0.2	0.8	0.1	0.1
February	1.2	0.3	1.0	0.2	1.2	0.2	0.2
March	1.5	0.4	1.4	0.3	1.2	0.2	0.3
April	1.6	0.5	1.5	0.4	1.4	0.3	0.4
May	1.7	0.6	1.6	0.4	1.5	0.4	0.5
June	1.9	0.5	1.6	0.5	1.5	0.5	0.5
July	1.7	0.4	1.6	0.4	1.5	0.5	0.4
August	1.6	0.4	1.5	0.4	1.4	0.4	0.4
September	1.3	0.4	1.4	0.3	1.3	0.3	0.3
October	1.2	0.3	1.2	0.3	1.1	0.3	0.3
November	0.9	0.2	0.9	0.2	0.9	0.1	0.2
December	0.9	0.1	0.9	0.1	0.8	0.1	0.1
Seasonal (Feb)	1.2	0.3	1.0	0.2			
Winter(1) (Dec, Jan,Feb)	0.9	0.2	0.9	0.2	1.2	0.1	0.2
Spring (Mar, Apr,May)	1.7	0.5	1.6	0.4	1.5	0.3	0.4
Summer (Jun, Jul,Aug)	1.9	0.4	1.6	0.4	1.5	0.5	0.4
Fall (Sept, Oct,Nov)	1.3	0.3	1.4	0.3	1.3	0.2	0.3
Annual	1.9	0.3	1.6	0.3	1.5	0.3	0.3

(1) Seasonal "Winter" data for baseline periods February 1975-January 1976 and February 1976-January 1977 are divided into February 1975 and December 1975-January 1976, and February 1976 and December 1976-January 1977, respectively

2.3 CLIMATOLOGY

This section presents a description of the general climatology of the region in which Tract C-a is located.

1. Objectives

It is the intent to establish a climatology by utilizing meteorological data collected from three sites surrounding the study area (defined as "onsite") and by comparison with both short-term and long-term climatic data available from stations in the region. The rugged topography of western Colorado causes variations in climate within short distances, and caution must be used when applying climatic generalizations to the whole area. Ideally, the most accurate way of characterizing the climatology of the C-a tract is to develop a long-term meteorological data base from meteorological data gathered onsite. The presently available onsite meteorological data base of three years cannot be construed as representative of the long-term climatic conditions in the tract area. The onsite data can be compared with similar short-term and long-term data in the region to identify site specific climatic idiosyncracies due to the orientation of mountain ranges and valleys, elevation and exposure.

2. Methods

Meteorological data have been collected onsite from four towers during the 1975-1977 baseline study (RBOSP 1977). Meteorological data for the period December 1977 - November 1978 (hereafter referred to as the current year) were collected from three of the towers on Tract C-a, and this information (reported in Section 2.2), in combination with future site data will be utilized in establishing a climatology for the tract.

The extent of climatological data available from regional National Weather Service stations has been investigated to provide comparisons with the collected onsite data. On a long-term basis, Grand Junction, Colorado is the only station in the region that has extensive and suitably summarized climatic data. The

Local Climatological Data for Grand Junction provided by the National Climatic Center (NCC) of the National Oceanic and Atmospheric Administration (NOAA) is the most comprehensive summary of the normals, means and extremes of temperature, precipitation, relative humidity, and wind data in the region (NCC 1978a). There are three other stations in Rio Blanco County for which short-term monthly temperature and precipitation data are available and these data are compared to the onsite monthly data during the current year (NCC 1978b).

3. Results and Discussion

Figure 2-18 presents the sources of data in the northwest section of the State of Colorado, where Tract C-a is located at an average elevation of approximately 7000 feet MSL. The weather stations closest to the tract are located in Rio Blanco County. Little Hills is the closest station, located about 15 miles to the northeast of the study area at an elevation of 6140 feet. The Meeker No. 2 station is located about 30 miles to the east-northeast at an elevation of 6347 feet. The Rangely station is located about 20 miles to the west-northwest at an elevation of 5220 feet. Grand Junction, at an elevation of 4843 feet is located furthest from the study area, at a distance of about 60 miles to the south of the site. Each of these stations monitors temperature and precipitation. At Grand Junction other parameters are measured as well.

The following is a discussion of the climatology of the area and the influences of the topography on the general meteorological and climatic conditions in the area. It has been extracted for reference from the Baseline Report (RBOSP 1977):

> The Tract C-a area is surrounded by high mountains. As a result, many migratory low pressure systems are deflected around the region. Stationary high-pressure cells often persist for several days, their passage blocked by the Continental Divide east of Tract C-a. As a result, there is a high frequency of clear sunny days with light winds and large diurnal temperature changes. Gradient winds are generally westerly, existing throughout the year, except when interrupted by the passage of frontal systems. Precipitation measurements

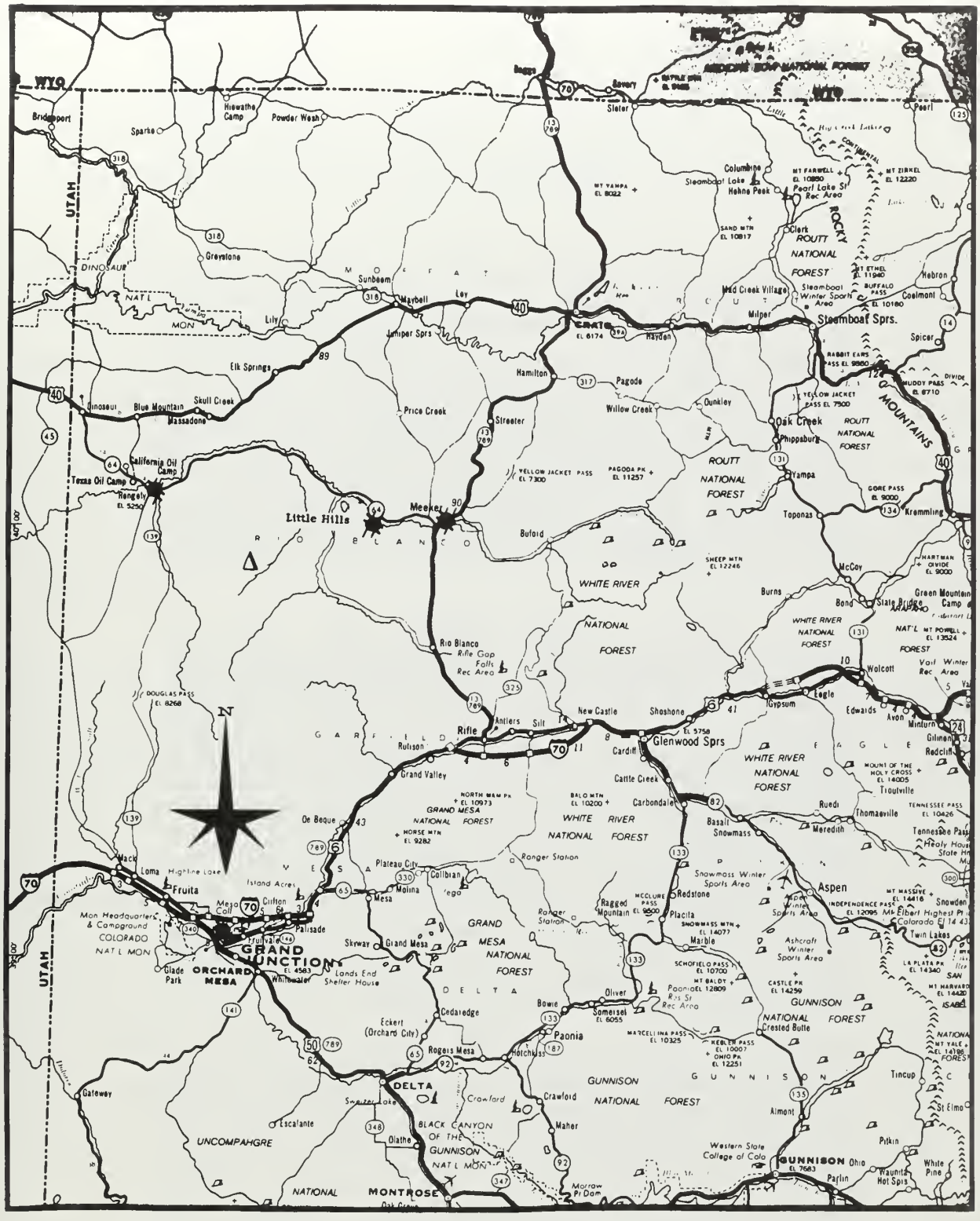


Figure 2-18. Map of Northwest Colorado Showing the Rio Blanco Region

indicate relatively low annual accumulations such as those of semi-arid steppe regions. In addition, the data indicate a high degree of temporal and spatial variability in this area, which is to be expected given the rough terrain with its variations in elevation and exposure. The infrequent occurrences of precipitation, fog, and small light-scattering airborne dust have produced excellent visibility, in general, for the Tract C-a area.

Local topography within the Tract C-a area has a much more pronounced effect on surface flows than the macroscale processes. Specific air movements produced by local conditions are often different from those expected from the major gradient flow. There is a tendency for wind velocities to be lowest at sunrise, when there is little vertical thermal mixing and the lower surface air does not couple with the more freely moving upper air. Conversely, velocities of local winds are greatest in the early afternoon hours when the air exhibits its greatest tendency to move vertically due to terrestrial heating, and couples with the faster air moving above it.

In the absence of strong gradient winds, the local terrain produces special meteorological conditions. During warm afternoon hours, the laterally constricted, but vertically expanding, air tends to flow up the valley. This air motion probably develops simultaneously with anabatic (upslope) winds which result from a greater heating of the valley side than the valley floor. At night, the reverse process occurs with the cold, dense air at higher elevations draining into the depressions. The greater radiative heat loss afffecting the higher elevations (especially if they are snow covered) cools the air immediately adjacent to the surface, and this air sinks into the valley. Downward flowing cold air set in motion by this effect forms downslope winds leading to an accumulation of cold, dense, stable air in the valley bottom.

The high Cathedral Bluffs to the west of Tract C-a and the deep gulches to the east effectively channel surface winds, and thereby decouple the upper level flows from the surface flows much of the time. Several studies have shown that airflow within the canyons of the Piceance Creek and Yellow Creek Basins is influenced by drainage winds in their respective channels, whereas winds measured atop the ridge-like portions of the basin closely follow the gradient wind regime. It can be inferred that these drainage winds occur in conjunction with stronger temperature inversions within the valley than at the ridge regions.

Meteorological data collected at the site during the current year can be compared to data for the same period from Grand Junction and to the Grand Junction long-term averages for the period 1941-1970. Table 2-29 shows the normals, means and extremes for Grand Junction, based on the record for the 1941-1970 period.

Table 2-30 presents the monthly departures from normal for Grand Junction mean temperature, total precipitation, mean relative humidity and mean wind speed during the current year. The departure during the current year of the mean annual temperature at Grand Junction from the long term average was +0.8°F. The Grand Junction mean annual temperature exceeded the RBOSC Site 1 mean during the current year by 7.8°F. The annual precipitation at Grand Junction for the period was 1.44 inches below the long-term average, while the Site 1 annual precipitation was 2.90 inches above the Grand Junction long-term average. Site 1 mean wind speed was slightly above the Grand Junction mean wind speed for the current year.

Table 2-30 indicates that Grand Junction data compares rather poorly with onsite data. Consequently, Grand Junction data should be used very cautiously in describing the climatology of the tract. This result is not unexpected, since Grand Junction is located in a valley approximately 2500 feet lower than Site 1. In fact, an estimate can be made of the temperature that would be expected if the Grand Junction station was at the same altitude as Site 1, by using the NACA Standard Atmosphere lapse rate for 40°N latitude of 3.57°F/1000 ft (Hess 1959). Using this approximation, the Grand Junction mean annual temperature would be reduced to 44.6°F, or 1.1°F below the mean for Site 1. Thus, the large descrepancy in mean annual temperatures between the site and Grand Junction can be accounted for by the altitude differential. However, it should be emphasized that topographic influences can also be large; whereas the standard lapse rate indicates that Site 3 should have a mean annual temperature 2.8°F higher than Site 1, the actual mean annual Site 3 temperature is 1.6°F lower than Site 1.

Table 2-31 presents monthly temperature data collected during the current year from Site 1, three surrounding climatological stations (Rangley, Meeker No. 2, and Little Hills), and Grand Junction. The table shows that Grand Junction

TABLE 2-29. LOCAL CLIMATOLOGICAL DATA FOR GRAND JUNCTION COLORADO DEPICTING NORMALS, MEANS AND EXTREMES BASED ON THE 1941 - 1970 PERIOD OF RECORD

Normals, Means, And Extremes

Month	Temperatures °F: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, ice pellets: Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity pct.: Hour 05 (Local time)	Hour 11 (Local time)	Hour 17 (Local time)	Hour 23 (Local time)	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F: Max (b) 90° and above	32° and below	Min. 32° and below	0° and below	Average station pressure mb. Elev 4839 feet m.s.l.
(a)				31		31					31		31		31		31		31		14	14	14	14	31	15	31	31		31	31	31	31	31	31	31	31	31	14	14	14	14	5
J	36.7	16.5	26.6	60	1971	-23	1963	1190	0	0.64	2.46	1957	T	1961	0.64	1956	33.7	1957	9.1	1957	77	66	62	75	5.6	ESE	84	S	1950	60	6.1	9	8	14	7	3	*	3	0	13	30	5	835.2
F	44.0	23.2	33.6	66	1976	-14	1951	879	0	0.61	1.56	1948	T	1972	0.53	1960	18.4	1948	8.6	1948	68	50	43	63	6.7	ESE	56	W	1967	65	6.1	8	7	13	6	1	*	2	0	2	24	1	834.1
M	52.8	29.6	41.2	81	1971	5	1948	738	0	0.75	1.75	1970	0.02	1972	0.78	1949	14.9	1948	6.1	1948	58	38	31	50	8.4	ESE	65	S	1954	65	6.0	9	8	14	7	1	1	1	0	*	20	0	847.9
A	64.6	38.8	51.7	85	1969	11	1975	404	0	0.79	1.95	1965	0.06	1958	1.33	1965	14.3	1975	8.9	1975	53	34	27	44	9.7	ESE	59	W	1955	67	5.8	8	10	12	6	*	2	*	0	0	8	0	849.1
M	75.8	48.5	62.2	95	1956	26	1970	133	47	0.63	1.79	1957	T	1970	0.74	1973	1.3	1975	1.3	1975	49	28	22	36	9.6	ESE	65	NW	1966	71	5.4	10	11	10	6	*	4	*	2	0	1	0	849.3
J	85.9	56.6	71.3	103	1971	34	1976	20	209	0.55	2.07	1969	T	1961	1.57	1969	0.0		0.0		45	25	20	33	9.8	ESE	66	S	1951	78	3.9	15	10	5	4	0	5	0	13	0	0	0	850.8
J	93.1	64.2	78.7	105	1976	48	1968	0	425	0.46	1.53	1974	0.03	1972	1.42	1974	0.0		0.0		47	28	21	36	9.3	ESE	56	SE	1955	77	4.2	14	12	5	5	0	8	0	26	0	0	0	853.0
A	89.1	61.6	75.4	103	1969	43	1968	0	322	1.05	3.48	1957	0.04	1956	1.21	1953	0.0		0.0		49	31	22	38	9.0	ESE	56	W	1957	75	4.3	14	11	6	7	0	8	0	21	0	0	0	853.1
S	81.3	53.0	67.2	98	1977	30	1971	60	126	0.84	2.52	1965	T	1953	1.35	1965	3.1	1965	3.1	1965	52	33	25	41	9.0	ESE	61	S	1947	79	3.5	17	8	5	6	*	5	0	4	0	*	0	853.4
O	67.9	41.9	54.9	88	1963	18	1975	324	11	0.93	3.45	1972	0.00	1952	1.24	1957	6.1	1975	6.1	1975	56	38	33	50	7.9	ESE	61	NW	1954	74	4.1	15	8	8	5	*	1	*	0	0	4	0	854.3
N	50.9	28.6	39.8	75	1977	-2	1976	756	0	0.61	1.69	1954	0.04	1976	0.82	1974	12.1	1964	8.4	1954	68	50	46	64	6.6	ESE	54	NW	1954	64	5.3	11	8	11	5	1	*	1	0	1	21	*	854.2
D	39.4	19.6	29.5	64	1973	-12	1962	1101	0	0.55	1.89	1951	0.01	1976	1.16	1951	16.7	1967	6.0	1967	75	62	59	73	5.9	ESE	48	NW	1951	60	5.8	10	7	14	6	2	*	2	0	7	30	1	854.9
YR	65.1	40.2	52.7	105	JUL 1976	-23	JAN 1963	5605	1140	8.41	3.48	AUG 1957	0.00	OCT 1952	1.57	JUN 1969	33.7	JAN 1957	9.1	JAN 1957	58	40	34	50	8.1	ESE	66	S	JUN 1951	70	5.0	140	108	117	70	9	34	8	66	24	139	7	852.4

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Maximum monthly precipitation 3.78 in September 1896; maximum precipitation in 24 hours 2.50 in October 1908; maximum snowfall in 24 hours 17.0 in November 1919.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

TABLE 2-30. MONTHLY DEPARTURES FROM THE LONG TERM NORMALS FOR THE DATA PERIOD DECEMBER 1977 - NOVEMBER 1978 FOR GRAND JUNCTION AND COMPARISON WITH RBOSC ANNUAL VALUES

Month		Temperature (°F) Long Term Mean	Temperature (°F) 1977-1978 Mean	Temperature (°F) Departure From Mean	Precipitation (inches) Long Term Mean	Precipitation (inches) Monthly 1977-1978 Mean	Precipitation (inches) Departure From Mean	Relative Humidity[1] (%) Long Term Mean	Relative Humidity[1] (%) Monthly 1977-1978 Mean	Relative Humidity[1] (%) Departure From Mean	Mean Wind Speed[2] (mph) Long Term Mean	Mean Wind Speed[2] (mph) Monthly 1977-1978 Mean	Mean Wind Speed[2] (mph) Departure From Mean
Grand Junction	December	29.5	33.3	+3.8	0.55	0.38	-0.17	67	64	-3	5.9	4.6	-1.3
	January	26.6	29.4	+2.8	0.64	1.08	+0.44	70	84	+14	5.6	4.3	-1.3
	February	33.6	34.4	+0.8	0.01	0.64	+0.03	56	68	+12	6.7	5.6	-1.1
	March	41.2	46.7	+5.5	0.75	1.19	+0.44	44	58	+14	8.4	6.3	-2.1
	April	51.7	52.3	+0.6	0.79	1.19	+0.40	40	43	+3	9.7	8.3	-1.4
	May	62.2	58.8	-3.4	0.63	0.55	-0.08	34	39	+5	9.6	8.1	-1.5
	June	71.3	73.0	+1.7	0.55	0.01	-0.54	31	24	-7	9.8	7.6	-2.2
	July	78.7	78.4	-0.3	0.46	0.25	-0.21	33	27	-6	9.3	8.5	-0.8
	August	75.4	74.5	-0.9	1.05	0.54	-0.51	35	29	-6	9.0	9.3	+0.3
	September	67.2	65.7	-1.5	0.84	0.49	-0.35	38	36	-2	9.0	8.4	-0.6
	October	54.9	54.7	-0.2	0.93	0.03	-0.90	44	36	-8	7.9	6.0	-1.9
	November	39.8	40.2	+0.4	0.61	0.62	+0.01	57	60	+3	6.6	5.5	-1.1
	Annual	52.7	53.5	+0.8	8.41	6.97	-1.44	46	47	-1	8.1	6.9	-1.2
RBOSC Site 1		-	45.7	-	-	11.31	-	-	34	-	-	7.6	-
RBOSC departure from Grand Junction		-	-7.8	-	-	+4.34	-	-	-13	-	-	+0.7	-
RBOSC Site 1 3-Yr Mean		(43.3)			(6.13)			(34)			(7.7)		

(1) Based on daily averages of 05, 11, 17, 23 (Mountain Standard Time)
Long term data record length is 14 years.

(2) Long term data record length is 31 years.

\- Not available

The RBOSC 3-yr mean data does not constitute a long term mean.

TABLE 2-31. COMPARISON OF MONTHLY TEMPERATURE (^{O}F) IN THE TRACT C-a VICINITY FOR THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

Month	RBOSC Study Site[1]			Rangely			Meeker No. 2			Little Hills			Grand Junction		
	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean
December 1977	33.6	23.2	28.6	42.5	16.2	29.4	41.9	19.5	30.7	43.1	17.2*	30.2*	43.3	23.3	33.3
January 1978	31.3	22.1	26.4	32.4	11.8	22.1	37.5	16.3	26.9	38.7	14.5	26.6	35.4	23.4	29.4
February 1978	32.7	22.6	27.3	37.6	13.4	25.5	39.7	16.4	28.1	41.5	16.4	29.0	42.5	26.2	34.4
March 1978	42.8	30.2	36.7	54.0	27.9	41.0	50.3	25.5	37.9	52.0	22.6	37.3	57.1	36.2	46.7
April 1978	48.4	34.3	41.0	64.7	34.2	49.5	59.5	30.4	45.0	59.5	27.1	43.3	64.5	40.1	52.3
May 1978	54.7	38.8	47.7	71.4	38.9	55.2	66.9	34.2	50.6	66.8	30.9	48.9	72.5	45.0	58.8
June 1978	71.6	54.3	64.2	86.8	48.9	67.9	79.8	41.5	60.7	80.9	36.5	58.7	89.2	56.8	73.0
July 1978	78.6	62.2	70.3	93.5	53.2	73.4	86.9	47.4	67.2	87.9	42.0	65.0	93.9	62.8	78.4
August 1978	74.3	56.5	65.8	89.4	49.8	69.6	83.6	45.8	64.7	84.2	38.9	61.6	89.7	59.3	74.5
September 1978	66.0	50.0	57.9	M	M	M	76.2	38.5	57.4	76.1*	30.2*	53.2*	80.7	50.7	65.7
October 1978	59.0	44.6	51.4	70.9*	31.4*	51.2*	67.6	29.5	48.6	66.4*	21.3*	43.9*	69.4	40.0	54.7
November 1978	36.3	25.5	30.2	42.9	19.6*	31.3*	48.1	19.3	33.7	45.1	14.2	29.7	50.9	29.4	40.2
Annual			45.7			46.9[2]			46.0[2]			44.0[2]			53.5

* One or more days of record missing
M Missing data
N/A Not available at time of report
(1) Temperatures provided are mean monthly values of Site 1 only
(2) Unweighted mean

temperature data are not very representative of at least part of Rio Blanco County. The mean monthly and annual temperatures at the three climatological stations in the county agree well with the onsite data, especially considering the elevation and topographic differences among the sites. A major difference between Site 1 and the other stations is evident, however, in the average maximum and minimum temperatures. Site 1 has a much reduced average temperature range compared to the other local stations. This is due primarily to the relative location of the instruments. All climatological stations measure temperature at 6 ft in a standard weather bureau shelter, whereas the Site 1 temperature sensor is located at 10 m (33 ft). Since temperature changes in the lower layers of the atmosphere result from heat transfer from the ground surface, the diurnal temperature range will decrease with height above the ground. Thus, the reduced temperature range at Site 1 relative to the surrounding station is due to the increased height of the temperature sensors at Site 1.

Table 2-32 presents a comparison of Site 1 precipitation data with data from surrounding stations for the current year. Monthly precipitation amounts at all of the stations vary widely due to the complex orographic influences of the region, but annual totals are reasonably close. Generally, the highest precipitation totals were found at the stations with windward locations, such as the Meeker No. 2 station. Grand Junction had the lowest monthly precipitation totals of all stations because of its protection by surrounding higher terrain.

The mean daily solar radiation received at Grand Junction (based on a 10-year period) is 456 langleys/day (Baldwin 1974). This compares to an average of 432 langleys/day recorded at Site 1 during the three years of data collection.

TABLE 2-32. COMPARISON OF MONTHLY PRECIPITATION (INCHES) DATA IN THE TRACT C-a VICINITY FOR THE DATA PERIOD DECEMBER 1977-NOVEMBER 1978, RBOSC

Month	RBOSC Study Site[1]	Rangely	Meeker No. 2	Little Hills	Grand Junction
	Amount	Amount	Amount	Amount	Amount
December 1977	0.35	0.43	0.63	0.70	0.38
January 1978	1.18	M	1.48	1.16	1.08
February 1978	0.75	0.38	0.95	0.70	0.64
March 1978	1.99	1.78	2.03	2.01	1.19
April 1978	1.56	1.04	1.38	2.18	1.19
May 1978	0.72	0.89	1.13	1.40	0.55
June 1978	0.81	0.56	0.95	0.28	0.01
July 1978	0.44	0.10	0.38	0.76	0.25
August 1978	0.57	0.73	0.61	0.49	0.54
September 1978	0.68	M	2.06	0.98	0.49
October 1978	0.20	0.75	0.12	0.20	0.03
November 1978	2.06	N/A	N/A2.03	1.68	0.62
Annual	11.31	N/A	13.75	12.54	6.97

(1) Site 1 annual average based on wedge gauge data only, since the only complete data set was obtained from this gauge type.
M Missing
N/A Not available at time of report

2.4 QUALITY ASSURANCE AND DATA RECOVERY

The data summaries incorporated in the Appendices, with the exception of precipitation and particulate data, were prepared from data acquired by an automatic data acquisition system located on Tract C-a. The data are recorded both on magnetic tape and analog strip chart recorders. A comprehensive quality assurance program has been maintained to ensure the reliability and accuracy of the data. This program includes documentation by the site technician, weekly zero and span calibrations of the air quality instrumentation, quarterly calibrations of the air quality instrumentation by both the internal technical staff and an independent auditing team, semi-annual calibrations of the meteorological instrumentation, and review of the analog and digital data by qualified analysts.

The air quality instruments are calibrated using pollutant sources traceable to NBS standards. The carbon monoxide analyzer was calibrated using a known concentration of a test gas which had been certified by the vendor. Calibration of the sulfur dioxide and nitrogen oxides instruments were conducted with permeation tube sources using a Monitor Labs calibrator. The applicability of the current Federal Reference Method for ozone using the Neutral Buffered Potassium Iodide (NBKI) technique has been shown to introduce a positive bias and questionable reproducibility. Consequently, in the middle of this one-year data period the ozone calibration was changed from the NBKI method to the gas phase titration method.

Each instrument was tested at least once a week by inserting a zero pollutant concentration and at least one upscale concentration. These tests provided data on instrument drift and insured that the instrument would respond to a sensible level of pollutant concentration in the ambient air.

The quarterly field calibrations were used to determine the accuracy of the instruments. No correction factors were required to adjust the data. The independent quarterly audits were used to check the internal calibration methods and were not used to adjust the data during this period.

The air quality data summaries include many hours where the concentration of some pollutants fell below the reliable threshold of detection of the instrument (based on the manufacturer's specifications). When this occurred, a number equal to one-half the threshold value was substituted for the data point. This procedure is adopted from the EPA Quality Assurance Handbook, Air Pollution Measurement, Vol. 1. This applied to sulfur dioxide, hydrogen sulfide, nitrogen oxides and carbon monoxide data acquired through much of the data period.

The meteorological system is calibrated on a semi-annual basis. This includes routine replacement of all wind speed and wind direction sensors. No correction factors were required to adjust the data.

Data recoveries for all meteorological and air quality parameters collected by the data acquisition system have been above the 75 percent level recommended by the EPA, and are presented in Tables 2-33 and 2-34. These data recoveries have been calculated on a very conservative basis without taking credit for periods of calibrations or of Force Majeure. That is, the values in the tables represent the ratio of the hours of actual recovered valid data to the total hours during the 12-month period.

TABLE 2-33. ANNUAL DATA RECOVERY (%) FOR THE PERIOD DECEMBER 1977-NOVEMBER 1978 FOR ALL METEOROLOGICAL PARAMETERS COLLECTED BY THE DATA ACQUISITION SYSTEM

Parameter	Data Recovery
Site 1	
10 m wind speed	89
10 m wind direction	90
60 m wind speed	90
60 m wind direction	90
10 m temperature	87
60 m temperature*	65
$\Delta T_{60\text{-}10\ m}$	87
dew point/relative humidity	86
solar radiation	90
Site 2	
10 m wind speed	86
10 m wind direction	86
10 m temperature	86
Site 3	
10 m wind speed	82
10 m wind direction	84
10 m temperature	85

* 60 m temperature not available on analog charts

TABLE 2-34. ANNUAL DATA RECOVERY (%)FOR THE PERIOD DECEMBER 1977-NOVEMBER 1978 FOR ALL AIR QUALITY PARAMETERS COLLECTED BY THE DATA ACQUISITION SYSTEM

Parameter	Data Recovery
Site 1	
O_3	89
CO	86
NO	81
NO_x	81
H_2S	83
SO_2	83
Site 3	
O_3	84
H_2S*	76
SO_2*	76

* Based on data recovery since January 12, 1978, when monitor was installed at the site.

2.5 VISIBILITY

Documentation of visibility in the Piceance Creek Basin is a cooperative study conducted by the Rio Blanco Oil Shale Company and the C-b Shale Oil Venture.

1. Objectives

The objectives of this program are to document the visibility in the area of the Piceance Creek Basin and identify trends or variations in visibility which may be evident during the monitoring program. The results of this program will provide visibility data against which past and future data may be compared and with which concurrent meteorological and air quality data may be incorporated for further evaluation and consideration.

2. Methods

The methods employed in the documentation of basin-wide visibility during this study incorporated techniques identical to those utilized during the baseline study conducted during 1975 - 1976, and described in RBOSC MDP Monitoring Report 1, and will not be discussed in detail in this report. Data are collected every sixth day during the two seasons: the Spring, represented by April and May, and the Fall, represented by October and November, from a centrally located shelter (Figure 2-19). Visibility measurements presented in this report were obtained during the Spring and Fall seasons, 1978. Approximately 460 measurements were obtained and used in the statistical analysis of visual range during the year.

3. Results and Discussion

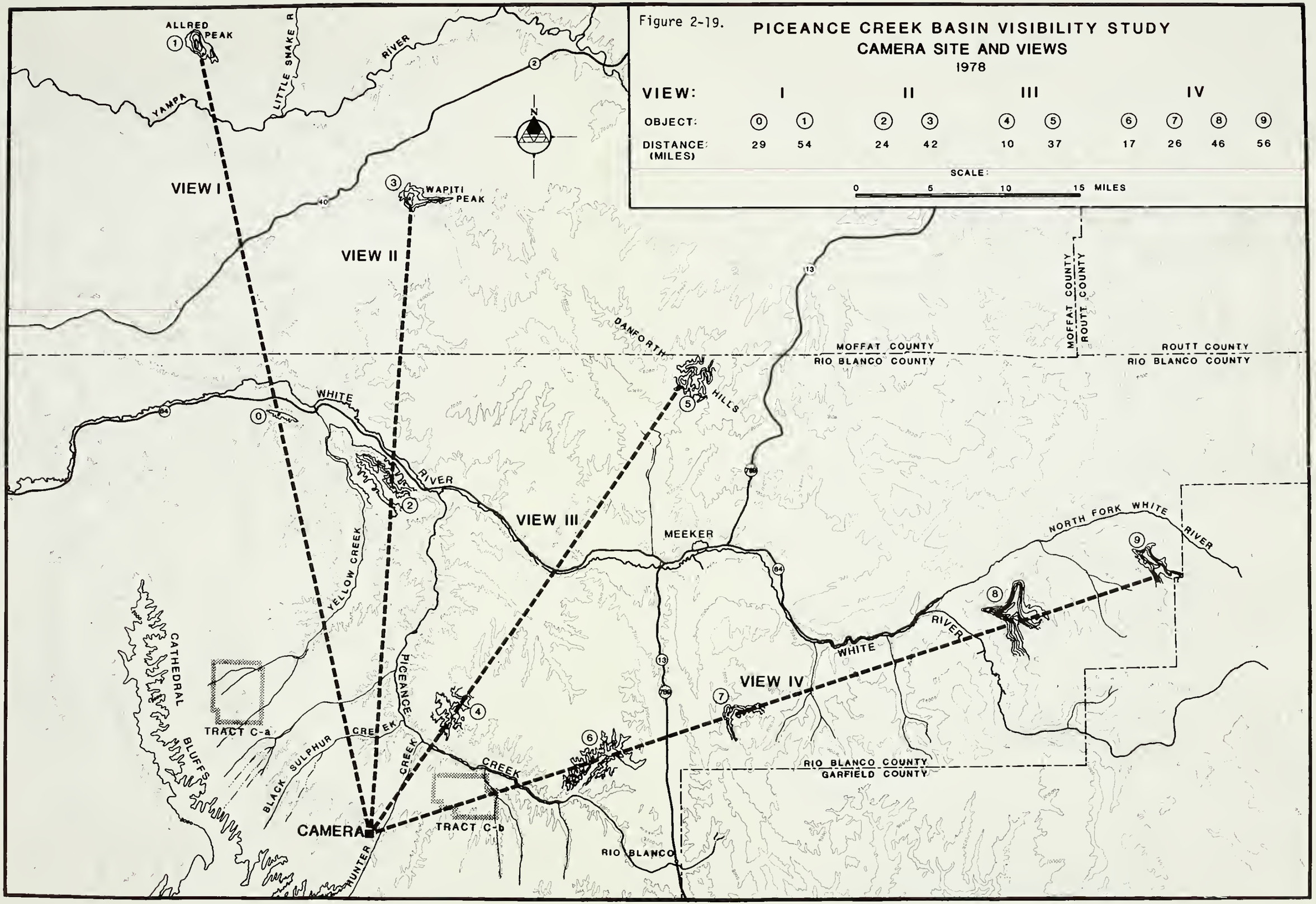
During the 1978 monitoring period, visual range measurements were made during 20 scheduled days of photography over a four month period. Of a possible 560 visual range measurements, 458 were obtained for an 82 percent data recovery; one day occurred in which no measurements were obtained for the views.

Figure 2-19.

PICEANCE CREEK BASIN VISIBILITY STUDY
CAMERA SITE AND VIEWS
1978

VIEW:	I		II		III		IV			
OBJECT:	⓪	①	②	③	④	⑤	⑥	⑦	⑧	⑨
DISTANCE (MILES)	29	54	24	42	10	37	17	26	46	56

SCALE: 0 5 10 15 MILES



Measurements of visual range during the year were occasionally hampered by passing rain or snowshowers which restricted visibility and made photography of the views difficult. Descriptions and examples of conditions of restricted visibility are presented in Appendix 2-5.1. The four general visibility conditions are: restricted, low, medium and high visibility. Accumulations of snow on some objects being photographed required adjustments to be made in their albedo. The resulting albedo for these objects was estimated using the original albedo of the object modified by the relative contribution of the snow. The albedo values used for the original objects' surfaces and for the additional snow cover were based on the spectral reflectance of snow and various soil types listed in the Handbook of Geophysics and Space Environments (Valley 1975).

3.1 Evaluation of Visual Range on a Daily Basis

The computation of a daily mean visual range provides an indication of the prevailing visibility and conditions found in an area during the course of a day, unbiased by short-term or directional anomalies. Daily mean visual ranges in the Piceance Creek Basin were calculated for each day of monitoring and the results are presented in Table 2-35; the hourly maximu, and minimum values are presented as well. No data are presented for November 28, 1978 due to inclement weather restricting the views for the entire day.

The daily mean visual ranges obtained during 1978 were generally high and occurred most frequently between 80 and 90 miles, although visual ranges over 100 miles and less than 30 miles were recorded. The hourly visual ranges used to compute the daily mean visual ranges for the Spring and Fall monitoring periods are included in Appendices 2-5.2 and 2-5.4, respectively.

Large fluctuations in the mean visual range of consecutive days of photography were common during 1978 with variations ranging from 2 to more than 40 miles. Between May 6 and May 12, 1978 for example, the mean visual range increased from 50 to 94 miles; the 6th of May was characterized by scattered

TABLE 2-35. DAILY MEAN VISUAL RANGE (MILES)
PICEANCE CREEK BASIN, COLORADO
SPRING AND FALL, 1978

	DATE	MEAN VISUAL RANGE	HOURLY MIN./MAX.
SPRING	April 6, 1978	102	72/142
	12	94	81/133
	18	81	72/112
	24	83	65/107
	30	54	21/84
	May 6, 1978	50	17/79
	12	94	71/114
	18	88	50/123
	24	66	44/94
	30	69	54/86
FALL	October 5, 1978	86	71/102
	11	80	55/123
	17	78	53/108
	23	100	79/130
	29	79	50/125
	November 4, 1978	90	58/121
	10	46	25/62
	16	29*	22/33
	22	55	32/83
	28	No Data	No Data

*Based on two hours of data.

snowshowers; May 12th by clear skies. Between April 18 and April 24, 1978, however, the mean visual range changed by only 2 miles, from 81 miles to 83 miles; both days were warm and sunny. The fluctuations exhibited in 1978 were generally smaller than during comparable periods in the 1975-1976 study. The average change in consecutive days of photography during the Spring and Fall, 1978 was 16 miles, compared with 28 miles during the same periods in 1975-1976. This decrease was most evident during the Fall monitoring period when the average variation was 19 miles, compared with 39 miles in 1975; the average fluctuation during the Spring of 1978 was 15 miles compared with 17 miles in 1976.

Daily mean visual ranges during the Spring of 1978 were higher than those recorded during the Spring of 1976, although extreme values were similar. During 1976, the maximum and minimum daily mean visual ranges recorded were 101 and 45 miles, respectively; during the Fall of 1975; mean values obtained during October and November, 1975 ranged from 63 to 130 miles, while the range in 1978 was from 29 to 100 miles. The hourly maximum and minimum values during the Fall also reflect this decrease. The single hourly maximum and minimum visual ranges during the comparable period in 1975 were 24 and 144 miles, respectively, compared with 22 and 130 miles during 1978.

The maximum daily mean visual range recorded in 1978 was 102 miles on April 6, 1978 and was reported in the Site Log as a "windy, blustery-type spring day". This contrasts with the minimum daily mean visual range of 29 miles recorded on November 16, 1978.

The fluctuations exhibited in the mean visual ranges, although large on occasion, were generally similar among the views; an increase or decrease in the mean visual range for an individual view was generally matched by similar response in the remaining views. These fluctuations, shown in Figure 2-20, illustrate the continuity in response of the views to changing visibility restrictions during the Spring and Fall monitoring periods. The correlation between fluctuations in daily mean visual ranges among the views implies that the influences on visibility were widespread and generally

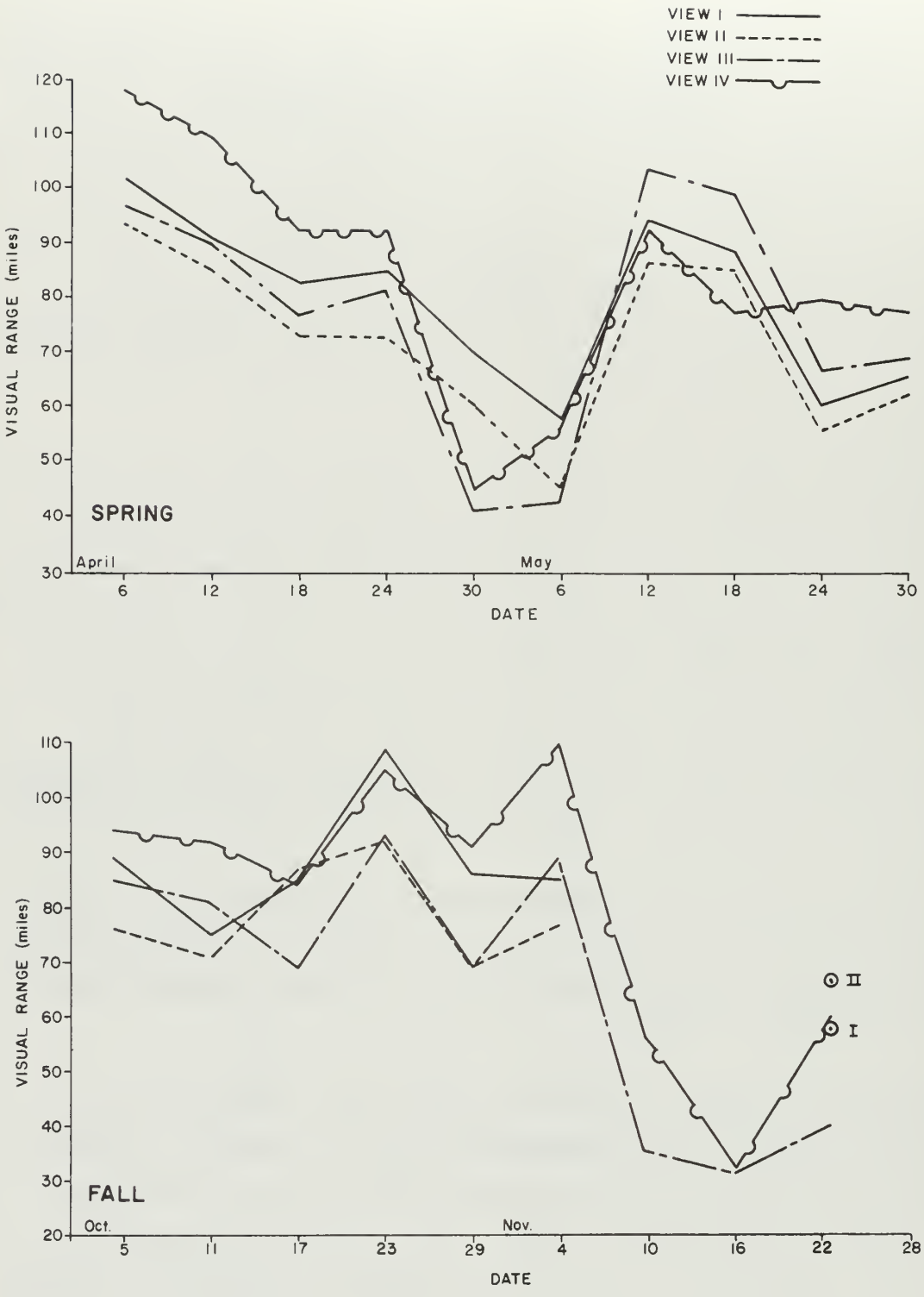


FIGURE 2-20
VARIATION IN DAILY MEAN VISUAL RANGE FOR EACH VIEW
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

uniform in the way they affected visibility. Data are not shown for Views I and II on November 10 and 16th due to inclement weather restrictions.

3.2 Evaluation of Visual Range on a Monthly Basis

Monthly mean visual ranges were calculated from measurements obtained from all the views and hours during each month of monitoring. The monthly mean visual ranges obtained in the Piceance Creek Basin Area during the Spring and Fall monitoring periods are listed in Table 36. Additionally, those visual range values obtained during comparable periods in 1975-76 have been included for review and comparison with the 1978 data.

Monthly mean visual ranges obtained during the four months of monitoring range from 70 miles in November to 84 miles in October; April and May had mean visual range for the four months of monitoring in 1978 (clear area) and for those same months during the 1975-76 (shaded area) monitoring period are represented in Figure 2-21. Values obtained during the May and October sampling months were more similar in the 1975-76 and 1978 periods than were the April and November values for the two periods. The monthly mean visual ranges for May and October are within 4 or 5 miles of those obtained during the 1975-76 periods; the monthly means for April and November varied from the previous study by as much as 29 miles. The distribution of visual ranges during April and November illustrate the large variation from those values obtained during the original monitoring period. During April, 1978 the distribution of hourly visual ranges was toward higher values than during April, 1976. Fifty percent of the observations during 1978 were greater than 85 miles, compared with 58 miles during 1976; the reverse is true, however, for November, 1978. The distribution of visual ranges during November, 1978 shifted to lower values than observed during November, 1975. Fifty percent of the visual ranges during 1978 were greater than 71 miles, compared with 102 miles in 1975.

Individual hourly maximum and minimum visual range measurements obtained in each month are also listed in Table 2-36. Individual hourly maximum and

TABLE 2-36. MONTHLY COMPOSITE VISUAL RANGE SUMMARY (MILES)
PICEANCE CREEK BASIN, COLORADO
SPRING AND FALL, 1978

MONTH	MEAN[a]	MAXIMUM	MINIMUM	STANDARD DEVIATION
April '78	83	142	21	21.1
April '76	*67*	*138*	*14*	*27.7*
May '78	74	132	17	20.5
May '76	*70*	*124*	*27*	*16.7*
October '78	84	130	50	16.2
October '75	*89*	*144*	*44*	*24.6*
November '78[b]	70	121	22	26.4
November '75	*99*	*149*	*24*	*29.0*

a) Monthly means are based on approximately five days of photography per month.

b) Values based on one full day and three partial days of photography.

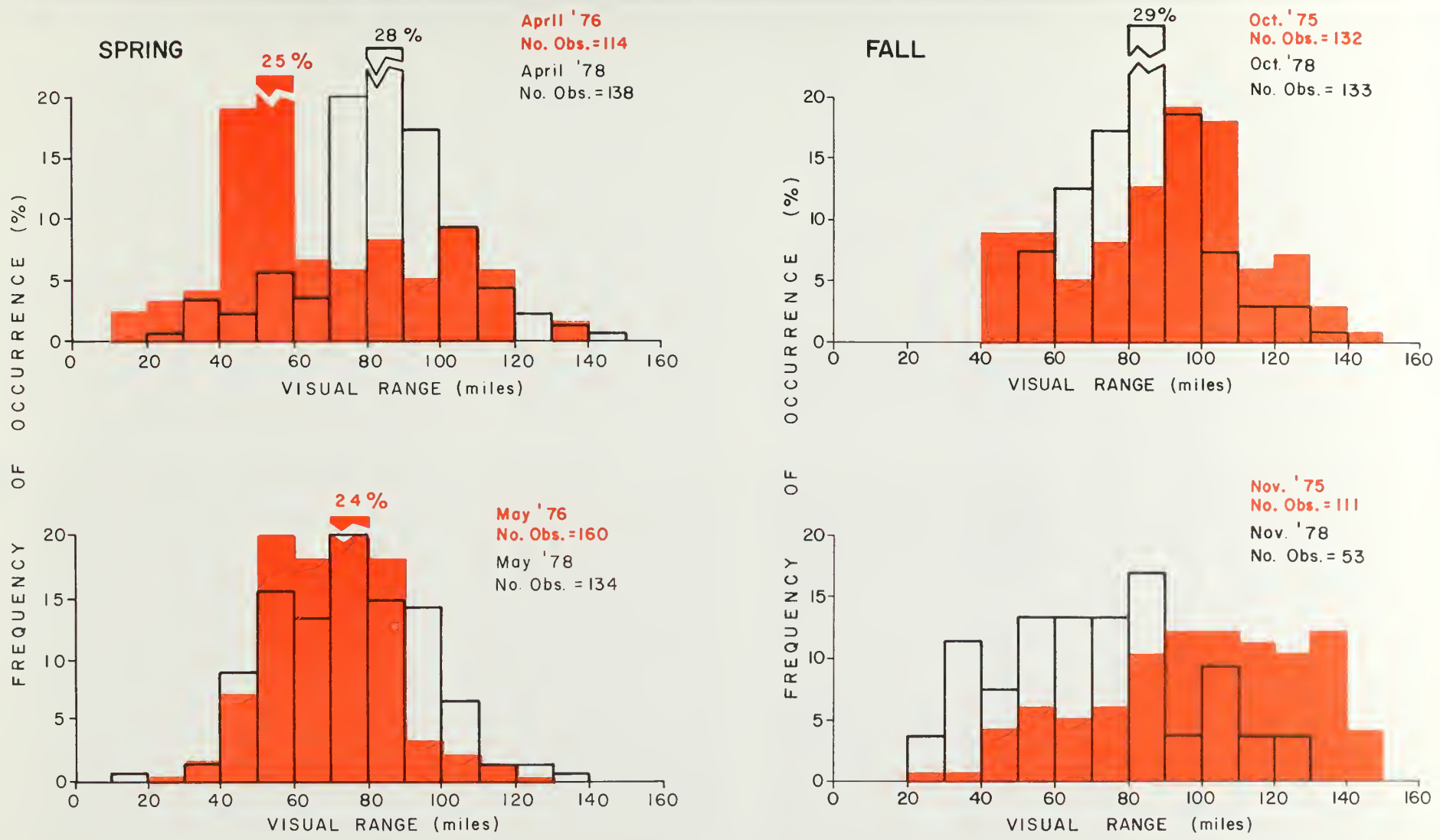


FIGURE 2-21

MONTHLY COMPOSITE DISTRIBUTION OF VISUAL RANGE
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

minimum visual ranges did not differ greatly from those obtained during the same periods in 1975-76. Minimum visual ranges varied from 17 to 50 miles during 1978, compared with 14 to 44 miles during the 1975-76 monitoring periods. Maximum visual range measurements varied from 142 miles to 121 miles in 1978; this compares with 149 miles and 124 miles during 1975-76.

3.3 Evaluation of Visual Range on a Seasonal Basis

Visual range measurements were made during two months in each of two of the four seasons in 1978 to quantify and characterize the visibility of the area. The selection of the Spring and Fall seasons for data collection was based on the results of the initial study during which the seasonal mean visual range was the minimum and maximum, respectively, during these seasons. Discussions in this section of the report deal with the comparison of visibilities encountered in those two seasons during 1978 and with those values obtained during the initial study of 1975-76.

The visual ranges obtained at Piceance Creek Basin during the two seasons in 1978 were generally high; the mean visual ranges were 79 miles during the Spring and 80 miles during the Fall. These and additional statistical descriptors are listed in Table 2-37 for each season and for the comparable seasons in 1975-1976. The data for 1975-76, however, includes three months per season, while the data for 1978 include two months per season, although the sampling frequencies were identical.

During the Spring, visual ranges were generally high; 95 percent of the visual range measurements were greater than 43 miles; 50 percent were greater 81 miles. This compares with 39 and 67 miles during the Spring of 1976, respectively. Visual ranges during the Fall were also high, but not as high as during the Fall of 1975. The mean visual ranges during the Fall of 1978 was 80 miles, compared with 91 miles in 1975. The mean visual ranges during the Fall of 1978 was 80 miles, compared with 91 miles in 1975. Ninety-five percent of the visual range measurements during the Fall of 1978 were greater than 43 miles; 50 percent were greater than 82 miles. This compares with 45 and 92 miles during the Fall of 1975, respectively.

TABLE 2-37. SEASONAL COMPOSITE VISUAL RANGE SUMMARY (MILES)
PICEANCE CREEK BASIN, COLORADO
SPRING AND FALL, 1978

SEASON	MEAN	HOURLY MAXIMUM	HOURLY MINIMUM	5 PERCENTILE	STANDARD DEVIATION
SPRING '78	79	142	17	43	21.2
Spring '76	*69*	*138*	*14*	*39*	*21.1*
Fall '78	80	130	22	43	20.5
Fall '75	*91*	*149*	*24*	*45*	*27.3*

TABLE 2-38. SEASONAL VISUAL RANGE SUMMARY (MILES), PICEANCE CREEK BASIN, COLORADO, SPRING AND FALL 1978

	VIEW	MEAN	HOURLY MAXIMUM	HOURLY MINIMUM	5 PERCENTILE	STANDARD DEVIATION
Spring	I	81 *(74)**	126 *(118)*	51 *(39)*	53 *(50)*	16.5 *(18.9)*
	II	73 *(63)*	112 *(113)*	32 *(32)*	42 *(40)*	17.1 *(16.5)*
	III	77 *(67)*	132 *(118)*	17 *(14)*	35 *(27)*	23.7 *(22.3)*
	IV	84 *(73)*	142 *(138)*	35 *(27)*	45 *(38)*	24.8 *(24.5)*
Fall	I	87 *(93)*	130 *(149)*	58 *(37)*	54 *(49)*	16.5 *(27.8)*
	II	76 *(77)*	102 *(142)*	55 *(42)*	54 *(43)*	11.7 *(23.6)*
	III	71 *(92)*	103 *(146)*	22 *(24)*	31 *(46)*	21.9 *(27.4)*
	IV	86 *(101)*	125 *(148)*	31 *(48)*	44 *(52)*	24.5 *(25.8)*

* Parenthetical numbers are from Spring 1976.

The hourly maximum and minimum visual ranges obtained during the Spring and Fall do not reflect the variation from the 1975-76 study noted in the mean visual ranges. Maximum and minimum values during 1978 were within 4 miles of those recorded during the same periods in 1975-76. The composite distribution of visual range in each of these is illustrated in Figure 2-22.

The change in the mean visual range (generalize visibility) seen during the seasons was also apparent in the mean visual ranges of the four views. The decrease in the Fall, 1978 mean visual range from the Fall, 1974 value and the increase in the Spring 1978 mean visual range from the Spring, 1976 value also appeared in all views; during no season did the mean visual range in an individual view vary from the general trend. The magnitude of changes varied, but not the direction. A summary of the mean visual ranges obtained in each view during the seasons is presented in Table 2-38 and illustrated in Figure 2-23. Included in Table 2-38 are the values obtained in the four views during each of the appropriate seasons in 1975-76; these values are listed in parenthesis.

The increase in the mean visual range noted in the Spring 1978 data was generally uniform in the four views. The mean visual ranges in Views II, III, and IV all increased by an amount equal to the increase of the generalized visibility during this period, i.e., 10 miles; View I increased by 7 miles; View IV by 11. The hourly maximum and minimums also increased, but not as uniformly as the mean values.

The change in the mean visual range in the Fall, 1978 data from the Fall, 1975 data was less uniform than that exhibited during the Spring and appears to have resulted primarily from decreases in the mean visual ranges of Views III and IV. The decreases noted in the Fall were 6 and 1 miles for Views I and II respectively compared with 21 and 15 miles in Views III and IV. The hourly maximums and minimums did not reflect the overall decrease in visual ranges. All hourly maximum values for the four views decreased: however, the minimum values did not.

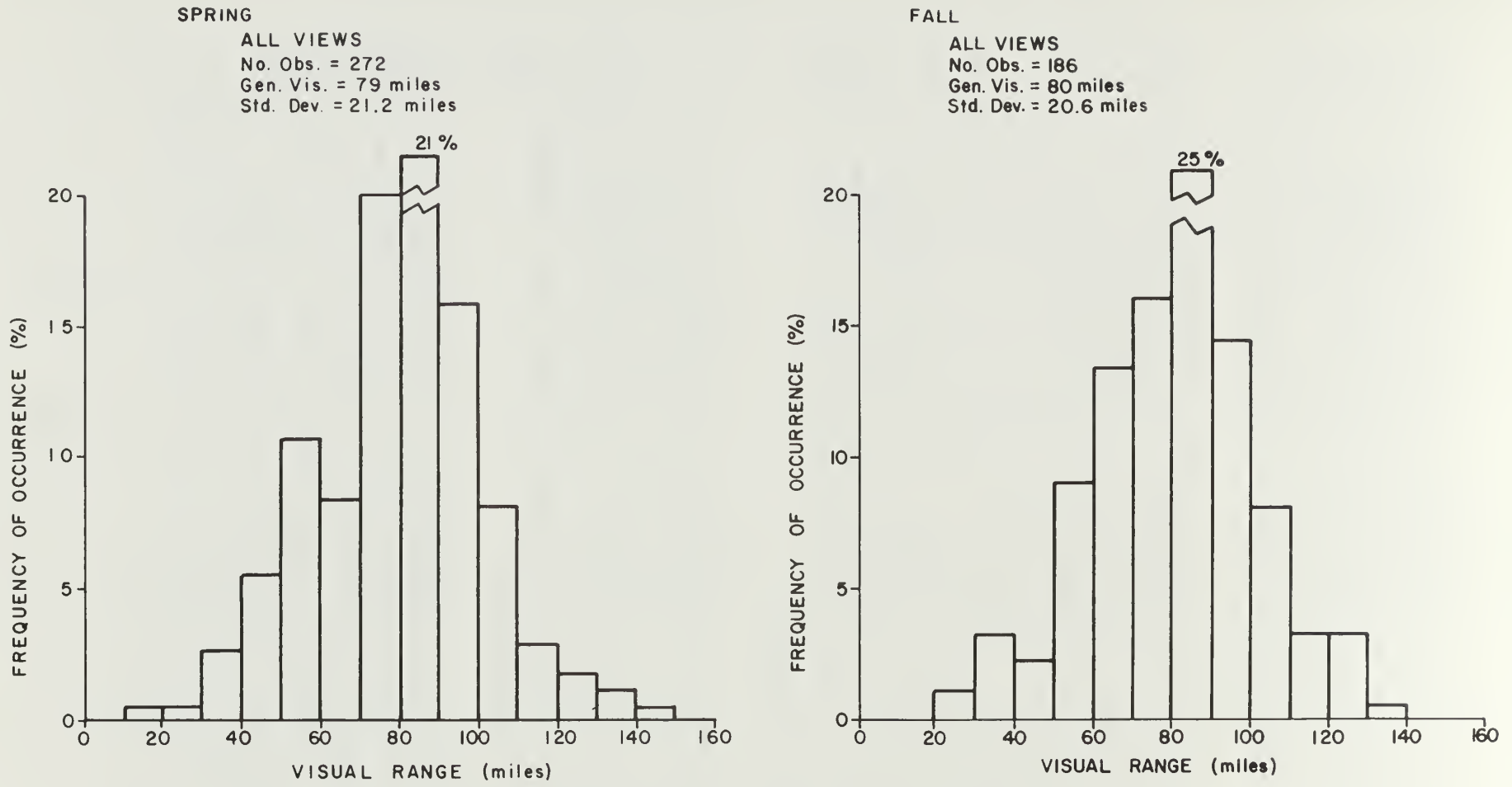


FIGURE 2-22
SEASONAL COMPOSITE DISTRIBUTION OF VISUAL RANGE
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

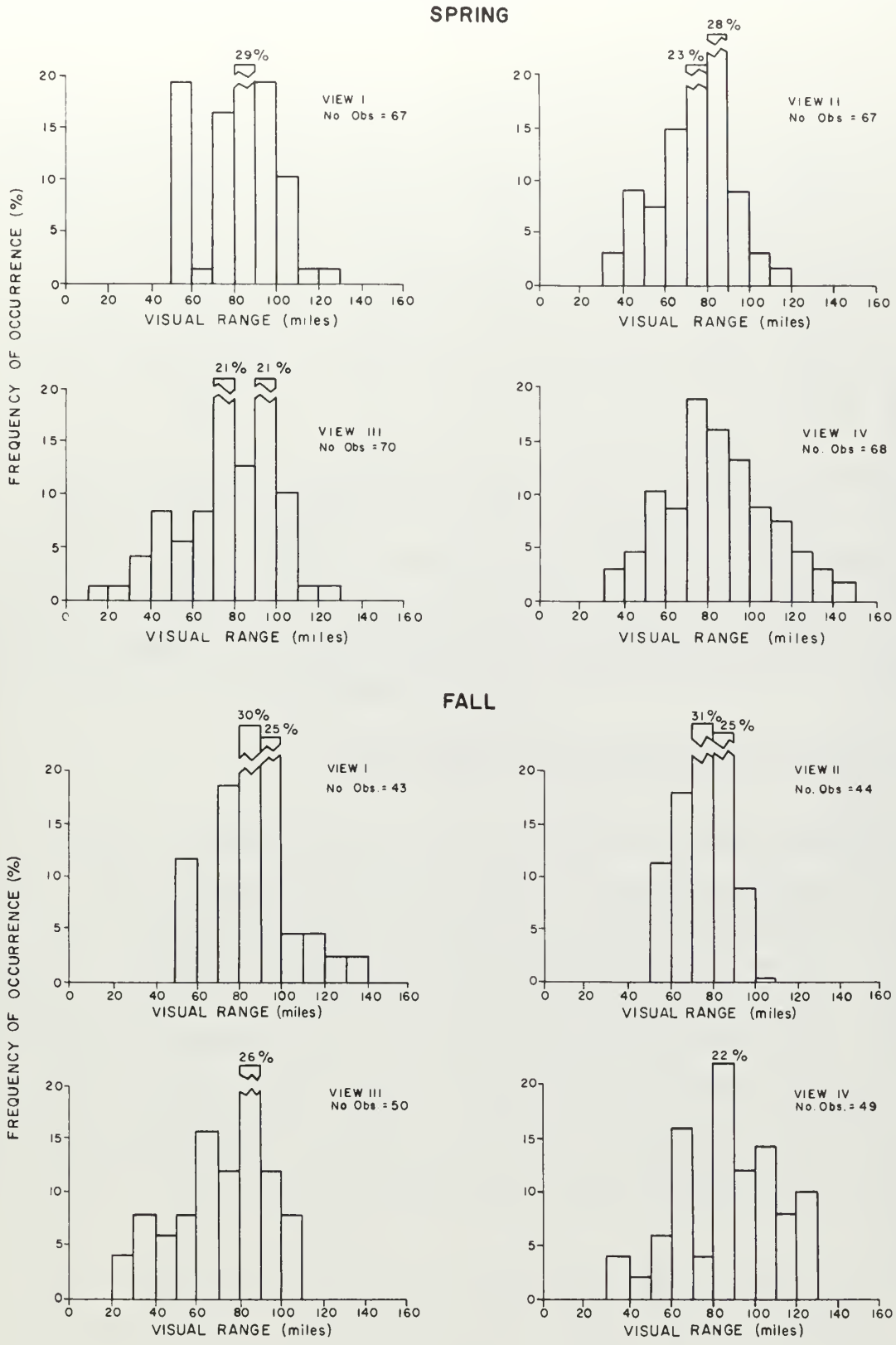


FIGURE 2-23
SEASONAL DISTRIBUTION OF VISUAL RANGE IN EACH VIEW
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

Another variation from the original study which appeared during the Fall of 1978 was the ordering of the magnitude of the mean visual ranges among the views. In every season during the 1975-76 study and the Spring of 1978, the lowest and second lowest mean visual ranges occurred in Views II and III, respectively. The highest mean occurred in either View I or IV; depending on the season. During the Fall of 1978, however, the relative ranking of Views II and II reversed; the difference in their mean visual range was 5 miles.

To investigate any hourly trend in visual range which might exist, mean hourly visual ranges were computed for each view and for the composite of views as shown in Figure 2-24. The separation of Views I and II from Views III and IV in Figure 2-24 facilitates comparison of the individual trends. Description of visual conditions as each mean hourly visual range photograph was taken are included as Site Log sheets in Appendices 2-5.3 and 2-5.5.

3.4 Evaluation of Visual Range on an Annual Basis

Visual range measurements made during this study were generally high; 95 percent of the values exceeded 43 miles; 50 percent exceeded 71 miles. The range of values obtained was also quite high; visual ranges varied from less than 20 miles to over 140 miles. The distribution of these values is presented in Figure 2-25 with a overlay of the distribution obtained during the 1975-76 study. The generalized visibility in the Piceance Creek Basin area during the 1978 study was 79 miles; this same value was obtained during the 1975-76 study.during the 1975-76 study. The generalized visibility in the Piceance Creek Basin area during the 1978 study was 79 miles; this same value was obtained during the 1975-76 study.

Hourly maximum visual ranges obtained during the year varied among the views; maximum values from 112 miles in View II to 142 miles in View IV were recorded. Hourly minimum visual ranges varied slightly more than the maximum values, ranging from 17 miles in View III to 51 miles in View I.

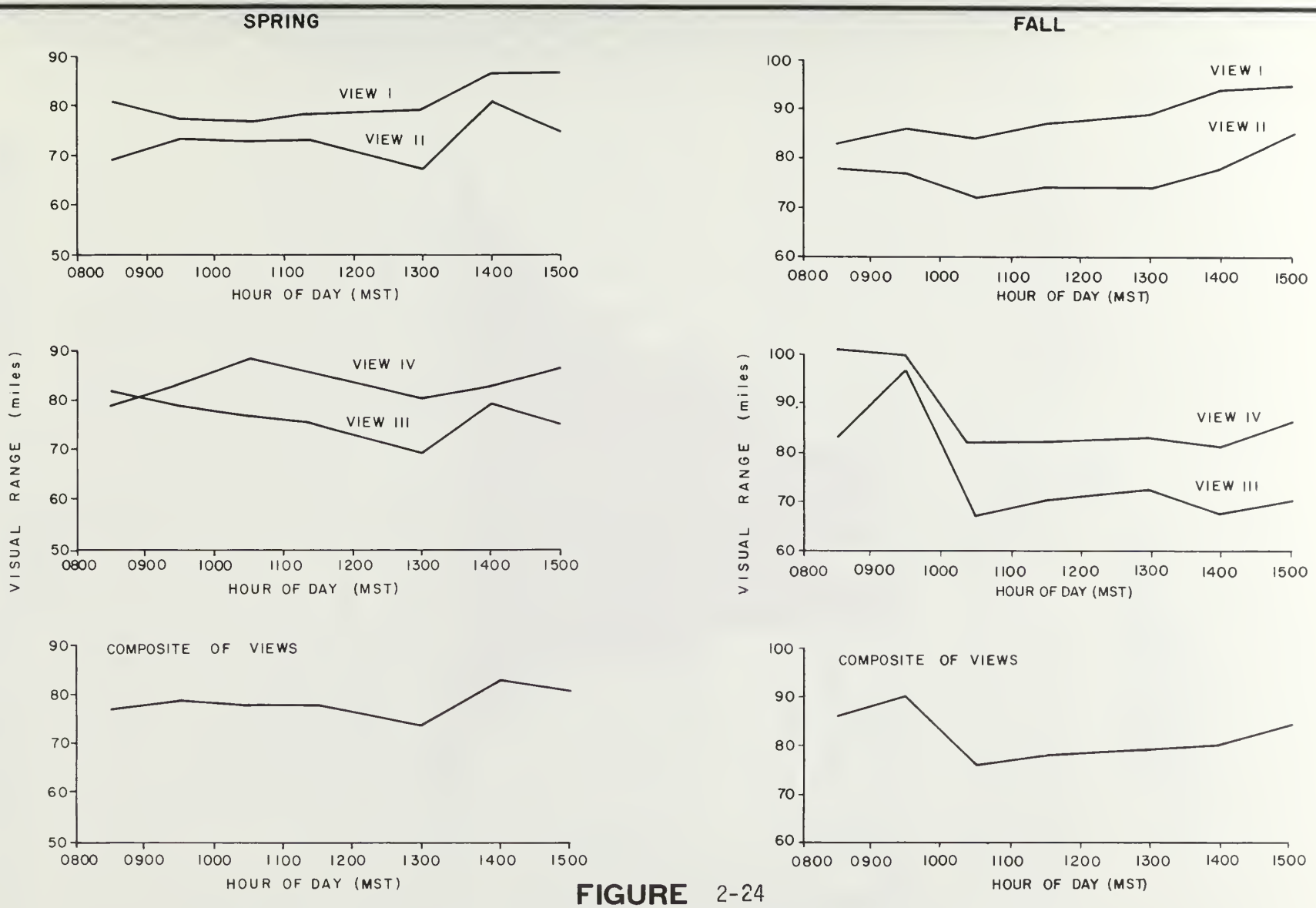


FIGURE 2-24

SEASONAL VARIATION IN MEAN HOURLY VISUAL RANGE
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

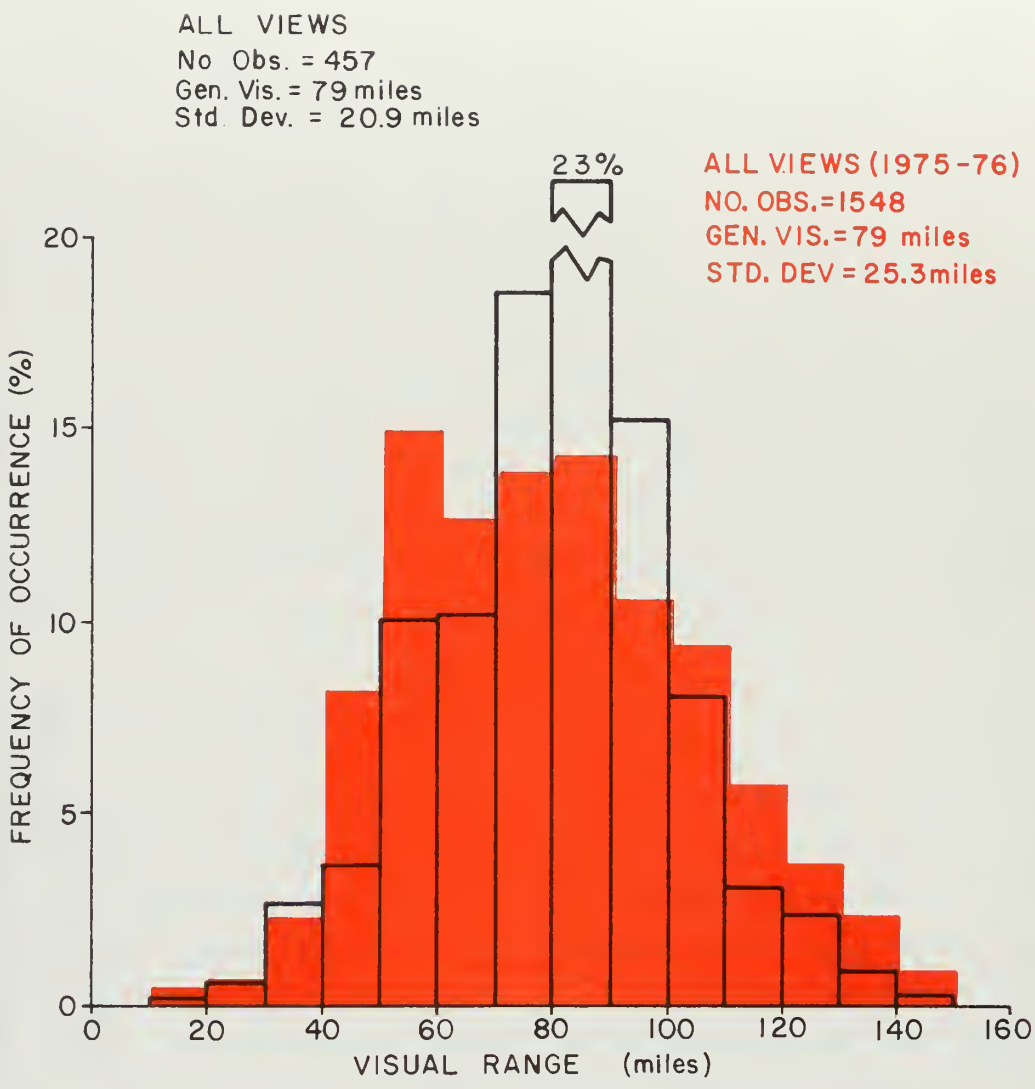


FIGURE 2-25
ANNUAL COMPOSITE DISTRIBUTION OF VISUAL RANGE
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

A summary of visual ranges obtained during the 1975-76 monitoring period and the 1978 period are presented in Table 2-39 for each view and for the composite of the views. The variation in the mean visual range of the four views presented in Table 2-39 is illustrated in Figure 2-26. (Shaded areas represents baseline data, clear area represents 1978 data).

The distribution found for View I is unusual. The largest percentage of visual ranges obtained in View I occurred between 50 and 60 miles. Distributions in View I similar to this were found during the 1975-76 study.

To investigate any hourly trend in visual range which might exist, mean hourly visual ranges for each view and for all views combined are presented in Figure 2-27 for each hour of photography. The separation of View I and II from Views III and IV in Figure 2-27 have been performed only to facilitate comparison of the individual trends.

The mean hourly visual ranges shown in Figure 2-27 reflect trends seen during the 1975-76 study. One general trend noted in the mean hourly visual ranges in Views I and II was a net increase in the mean visual range during the day which was also seen during 1975-76. In Views III and IV, the mean visual range in View III remained lower over the course of the day than were obtained in View IV - also seen during the 1975-76 study. The composite of the four views is also illustrated in Figure 2-27. On an "average" day, the mean hourly visual range increases slightly during the second hour of the day, then decreases to near the early morning level and remains there until early afternoon when it begins a gradual increase through the remainder of the afternoon.

TABLE 2-39. ANNUAL VISUAL RANGE SUMMARY (MILES), PICEANCE CREEK BASIN, COLORADO, SPRING AND FALL 1978

VIEW	MEAN	HOURLY MAXIMUM	HOURLY MINIMUM	5 PERCENTILE	STANDARD DEVIATION
I	83 *(83)**	130 *(149)*	51 *(31)*	53 *(50)*	16.7 *(23.0)*
II	74 *(69)*	112 *(142)*	32 *(31)*	46 *(42)*	15.2 *(19.2)*
III	74 *(78)*	132 *(149)*	17 *(14)*	33 *(35)*	23.0 *(26.6)*
IV	85 *(85)*	142 *(148)*	31 *(22)*	45 *(41)*	24.6 *(28.8)*
COMPOSITE	79 *(79)*	142 *(149)*	17 *(14)*	43 *(41)*	20.9 *(25.3)*

*Parenthetical numbers are from the 1975-76 study.

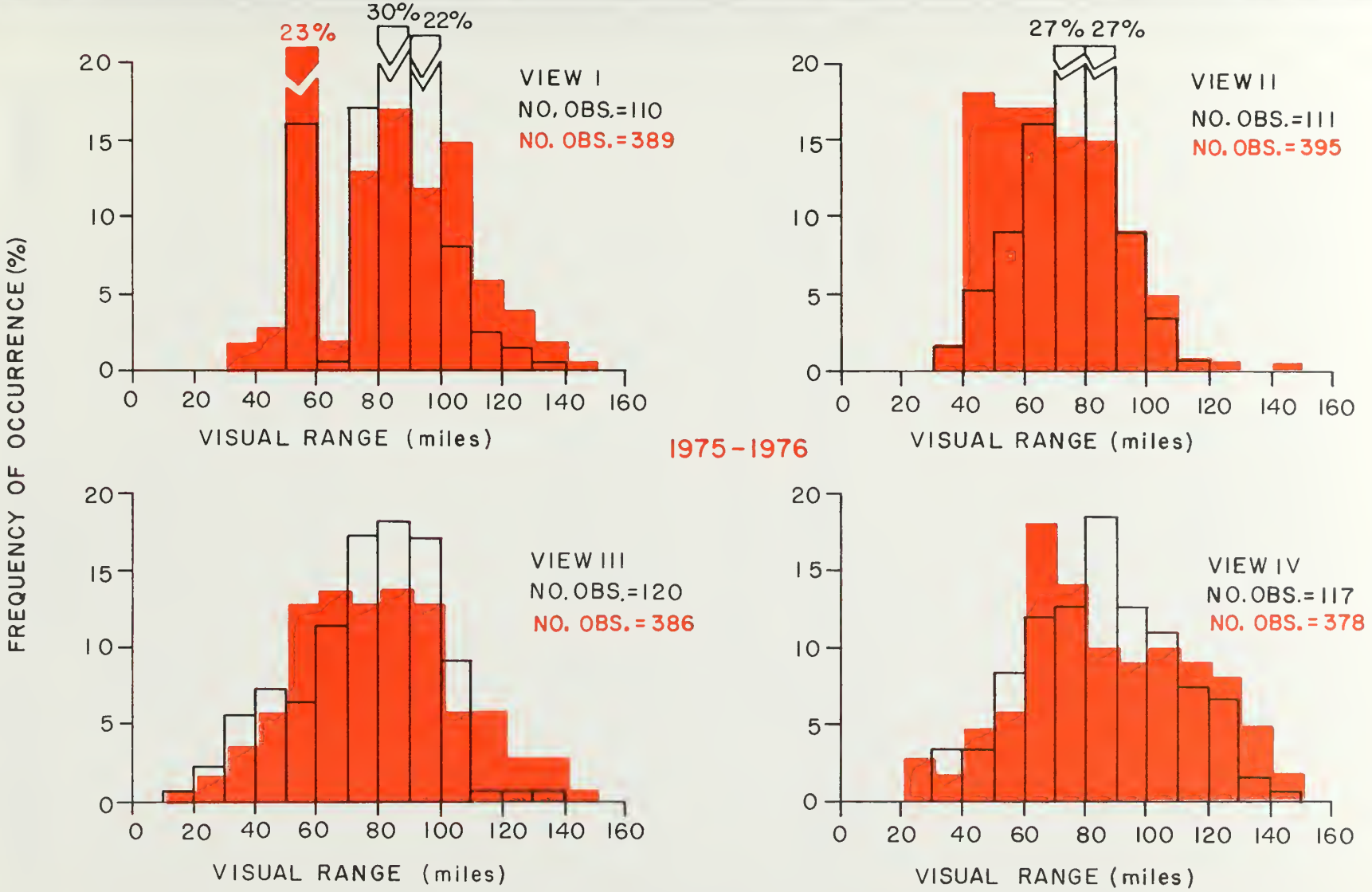


FIGURE 2-26

ANNUAL DISTRIBUTION OF VISUAL RANGE IN EACH VIEW
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

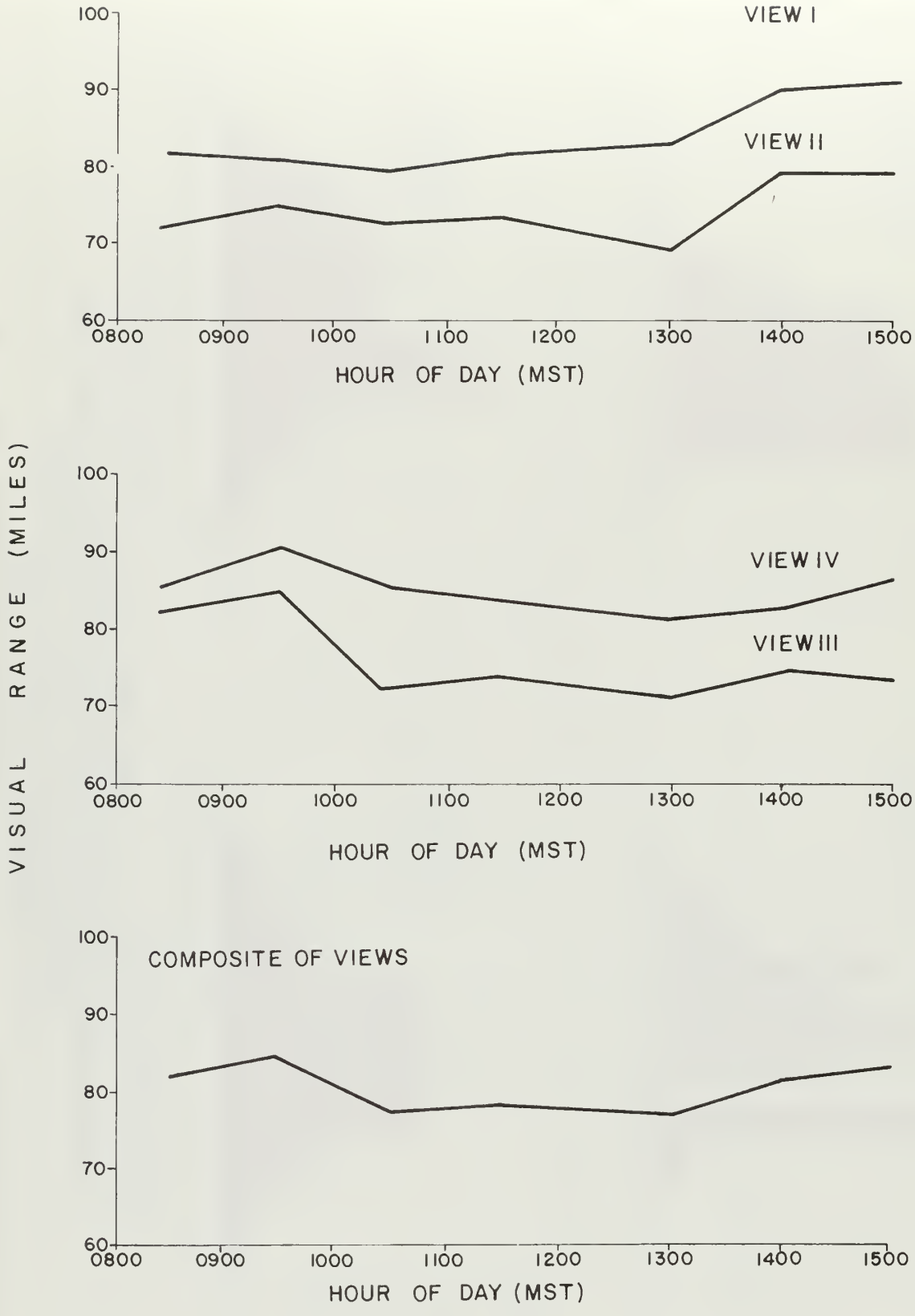


FIGURE 2-27
ANNUAL VARIATION IN THE MEAN HOURLY VISUAL RANGE
PICEANCE CREEK BASIN, COLORADO
SPRING and FALL, 1978

study. The composite of the four views is also illustrated in Figure 2-27. On an "average" day, the mean hourly visual range increases slightly during the second hour of the day, then decreases to near the early morning level and remains there until early afternoon when it begins a gradual increase through the remainder of the afternoon.

2.6 NOISE

Development activities on Tract C-a will result in increased noise levels in the area. In order to assess the potential effects of these increased noise levels, it will be necessary to identify the sources of the noise and the intensity of noise levels at various distances from these sources. The RBOSC noise survey is designed to provide these data.

1. Objectives

Regulations regarding allowable noise levels have been promulgated for the safety and well being of humans. None of the existing regulations apply to effects of noise on wildlife, although some research has been conducted in this area (EPA 1971, Effects of noise on wildlife and other animals, Memphis State University). The objectives of the environal noise program are to:

- Provide a data base on relative noise levels at various distances from sources on the tract

- Provide data for use by wildlife biologists in assessing the overall impacts of tract development on wildlife behavior and use of the study area.

2. Methods

In order to acquire the necessary noise level measurements, sound level readings are taken once each quarter at strategic monitoring sites around the mine development area. During the period of study, two surveys of noise measurements were taken. The two surveys, taken on August 3 and October 26, 1978, consisted of noise measurements at 15 monitoring sites arranged in a configuration of concentric circles at various distances from the area of mine activity out to the borders of Tract C-a (Figure 2-28). One other reading was taken in close proximity

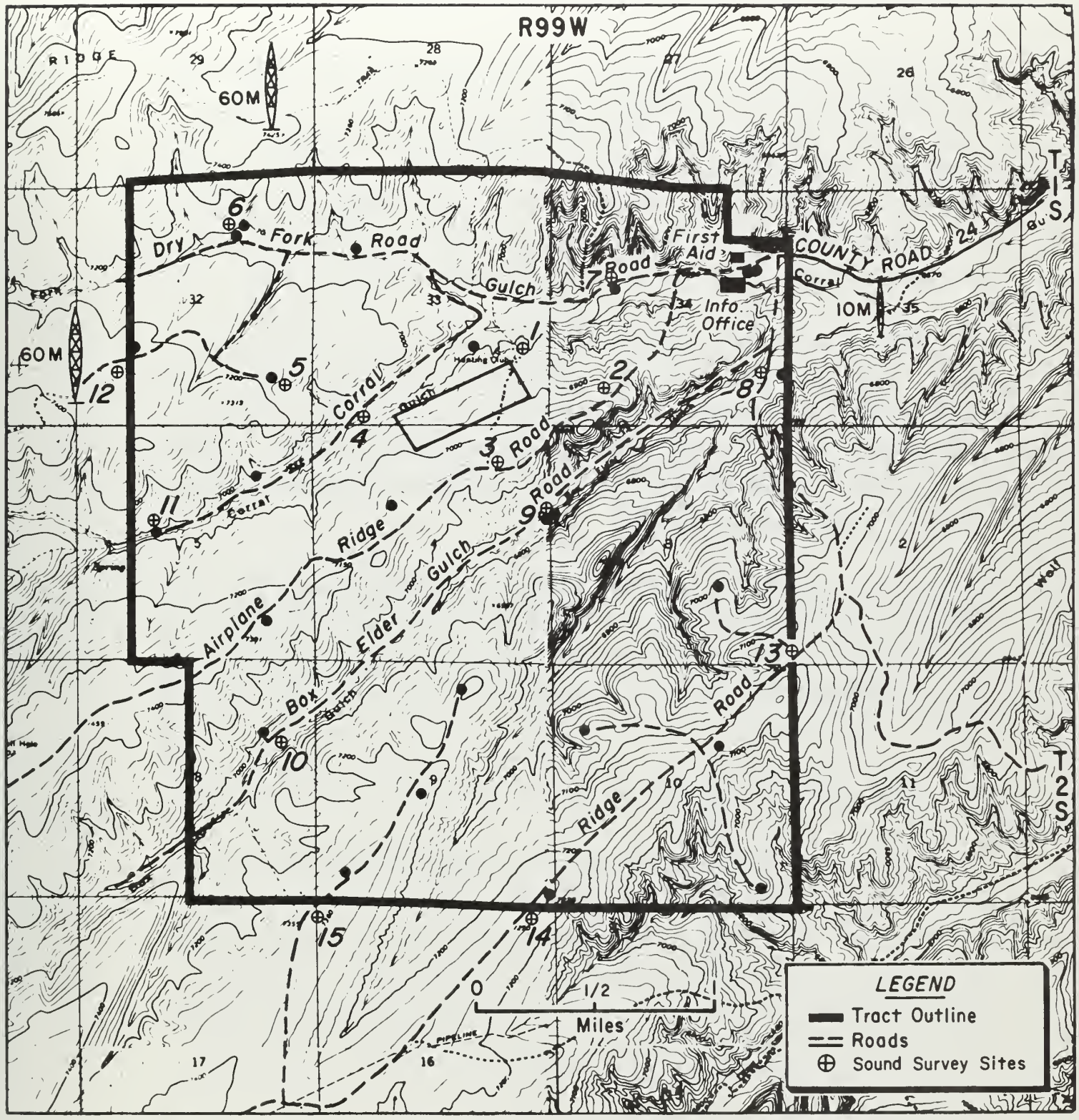


Figure 2-28 Environmental Sound Level Monitoring Sites, RBOSC Tract C-a

to the headframe for an indication of highest noise production. Precise locations of these monitoring sites are described in Table 2-40.

Sound level readings are taken with a Bruel and Kjaer Sound Level Meter, Type 2205, which has an accurate range of 20 to 130 dB. A Condenser Type 1, ANSI S1.12 omnidirectional microphone is used to receive noise impulses. The sound level meter is calibrated with a Bruel and Kjaer Sound Level Calibrator, Type 4230 operating on a frequency of 1000 Hz ± 1%. Wind speed is determined with a Taylor Instrument Company, handheld anemometer. Wind direction is estimated with the aid of a compass.

The sound level meter is calibrated before each survey. Wind speed (mph), wind direction, and time is recorded at the start of each survey. Highest and lowest values on the meter during a 30-second period are recorded for each site. Measurements are repeated five times. Comments noting unusual circumstances (i.e., jet overhead) and general conditions during the reading are recorded.

Sound level readings are reported as highest and lowest range for each of the five readings at each site and as the sound level average of all five samples. Averages are determined by adding all 10 values for each site and dividing by 10. Values are reported in decibels with A weighting (dBA), slow response.

3. Results and Discussion

Sound level reading taken during the two surveys are shown in Tables 2-41 and 2-42. The highest average decibel level was 65 dBA in the August survey and 69 dBA in the October survey. Both of these readings were obtained at the monitoring stie near the headframe. Background noise levels were in the order of 25 dBA and were reached when readings were taken at distances greater than about one mile from mining activities. These same general decibel levels were found in readings taken on site boundaries. Exceptions to background noise were noted when

TABLE 2-40. LOCATIONS OF ENVIRONMENTAL NOISE MONITORING SITES, TRACT C-a

Site Number	Locations/Descriptions
1	Top of knoll N.E. of Hunting Camp, E. of road down to Corral Gulch
2	Left side of site access road, 20ft S.W. of "Hill" signs
3	N.E. corner of intersection of Airplane Ridge Road and tank access road
4	Left side of Corral Gulch Road at fence corner slightly past power line crossing
5	100ft. S.E. toward site from well CE-707, on line between survey pt. and site
6	Up small incline N.W. of Well TO-2 outside of fence, 10ft. W. of survey pt.
7	Right side of Gulch Road at Well GS-45, on top of road cut
8	Off right side of road on small knoll directly across from entrance to well GS-6 and trailer camp
9	North side of fenced area at WE11 TO-1 near entrance
10	South side of Box Elder Gulch Road at N.E. fence corners for well Am-3
11	Up side of road out, right side of Corral Gulch Road at turn around area, across from stream gorge GSSH7 Box
12	Left side of road to Met. Sta. #1, 0.1 mile from power line crossing and S.W. corner of well GS-10.
13	Right side of Ridge Road, N.E. corner of intersection into well GS-10
14	Left side of Ridge Road at Tract C-a boundary line.
15	Right side of road, 0.15 mile north of access road into 10M Tower, opposite small dirt road on the left.

TABLE 2-41. ENVIRONMENTAL SOUND LEVEL MEASUREMENTS, RBOSC TRACT C-a, AUGUST 8, 1978.

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (30 sec) 1	2	3	4	5	Sound Level dBA Range	Sound Level dBA Average	Remarks
1	9:40am	Calm	54-55	54-55	52-53	52-54	52-52	52-55	53	Gen. running at H.C.
2	10:52am	Calm	31-38	31-35	33-36	30-33	31-35	30-38	33	No traffic during test
3	11:08	Calm	41-42	38-42	39-42	39-40	38-40	38-42	40	Job noise audible
4	10:21	Calm	37-42	37-40	39-45	44-48	39-45	37-48	42	Large trucks hauling in pit
5	10:00am	Calm	28-32	30-32	32-34	29-31	29-31	28-34	31	Back-up alarms audible
6	9:51am	Calm	25-25	24-25	25-25	24-26	25-28	24-28	25	Noise from job audible
7	10:40am	3-5/E	37-42	38-40	37-45	42-45*	31-34	31-45	39	Trucks driving on access road
8	12:24pm	Calm	27-30	26-29	24-28	24-25	24-25	24-30	26	Trucks audible on road
9	11:18am	Calm	25-27	26-28	24-27	25-26	24-26	24-28	26	Job not audible
10	11:28am	3-5/E	25-26	27-28	25-26	29-29	27-32*	25-32	27	Job not audible
11	10:28am	Calm	25-26	24-25	26-27	26-28	26-27	24-28	26	Sound of water in gulch "trickling"
12	10:09am	Calm	26-26	25-27	24-26	25-25	23-25	23-27	25	Noise from job audible
13	12:07pm	Calm	25-25	25-26	24-26	25-27	25-25	24-27	25	Job not audible
14	11:52am	Calm	25-27	26-28	25-26	24-26	24-25	24-28	26	Job not audible
15	11:41	Calm	25-25	25-28	24-26	24-25	24-25	24-28	25	Job barely audible
A	11:00am	Calm	62-64	62-68	66-76	62-66	61-64	61-76	65	60'E of Headframe

Note: Instrument calibrations before and after the survey revealed that the instrument was within specified limits

* Commercial jets overhead

TABLE 2-42. ENVIRONMENTAL SOUND LEVEL MEASUREMENTS, RBOSC TRACT C-a, OCTOBER 26, 1978.

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (30 sec) 1	2	3	4	5	Sound Level dBA Range	Sound Level dBA Average	Remarks
1	10:23am	Calm	47-49	48-49	48-49	48-49	49-51	47-51	49	H. C. Gen. audible
2	10:45am	Calm	29-32	29-32	24-39	38-46	29-33	29-42	34	Trucks audible from Dry Fork Gulch Road
3	10:37am	Calm	46-49	46-48	45-48	46-47	47-48	45-49	47	Gen. at water truck audible
4	9:11am	Calm	38-39	36-38	34-39	35-36	34-36	34-39	37	Generator audible
5	8:53am	Calm	38-41	33-37	35-37	35-39	35-37	33-41	37	Heavy equipment audible
6	8:40am	Calm	32-33	33-33	36-39	34-38	36-40	32-40	35	Heavy equipment audible
7	8:30am	Calm	31-36	32-37	36-38	33-33	33-34	31-38	34	Job noise audible
8	11:45am	Calm	38-44	38-40	37-40	37-42	39-44	37-44	40	Well service rig at well G-S6
9	10:55am	3-5/E	22-32	23-26	22-23	22-23	23-26	22-32	24	Job noise audible
10	11:04am	Calm	21-22	22-22	20-22	20-21	21-21	20-22	21	Job noise audible
11	9:19am	Calm	46-46	46-47	46-47	46-46	47-48	46-48	47	Job noise audible - Noise from drilling 300 yards SW of site
12	9:01am	Calm	24-24	24-25	23-24	23-24	24-24	23-25	24	Job noise audible
13	11:32am	Calm	24-25	23-25	23-24	23-24	23-24	23-25	24	Job noise audible
14	11:24am	Calm	23-25	22-23	22-23	22-22	22-23	22-25	23	Job noise audible
15	11:14am	Calm	23-23	23-23	22-23	23-24	22-23	22-24	23	Noise from Met. Sta. audible
A	10:51am	Calm	61-78	61-66	66-69	68-77	68-76	61-78	69	100' E of Headframe

Note: Instrument Calibrations were made at 8:20 and 11:53 am. The instrument was within allowable limits.

there was aircraft passing overhead, vehicular traffic in the area or some other activity (e.g. drilling) near the monitoring site.

Noise levels taken during these two surveys were generally lower than those taken during the January and March surveys as reported in MDP Report 2. Differences in wind speed and location of monitoring sites may account for the dissimilar readings.

The potential for wildlife disturbances due to noise of this magnitude during late summer and fall is anticipated to be small. Noise level readings taken in conjunction with breeding bird surveys in the spring may provide more useful information.

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SECTION 3

TERRESTRIAL STUDIES

The Terrestrial Studies MDP Monitoring Program is designed to detect and evaluate those impacts affecting the soil, vegetation or faunal components of the terrestrial ecosystem on or near RBOSC Tract C-a. An intensive two-year terrestrial program was conducted from October 1974 through September 1976 to characterize the biotic conditions existing prior to MDP development. Specific terrestrial baseline studies included soils, vegetation, range and browse, small mammals, large mammals, mammalian predators, reptiles and amphibians, avifauna, domestic livestock, and terrestrial invertebrates.

The terrestrial monitoring program is based on an assessment of current knowledge of MDP mining operations. Environmental parameters which are either expected to be affected by developmental activities or are ecologically or politically important have been included in the terrestrial monitoring program. Because this is a prototype operation, new information may become available which requires a modification of the outlined program. Therefore, this monitoring program should be viewed as a flexible one which may change as engineering design is refined and as additional ecological data are obtained.

The following section presents results obtained during June - November, 1978.

3.1 SOILS

A. Trace Metals

Particulate releases (~11 lb/hr) during the MDP will be quite low and maximum concentrations are not expected to be sufficient to affect the soil stratum. However, accumulation over several years may result in measureable increases in these constituents. Precautions will be taken to prevent such emissions in accordance with appropriate federal and state air pollution regulations.

1. Objectives

The objective of the trace metal study is to detect any accumulation of trace metals in the soils, and subsequent accumulation in the vegetation, should trace metal emissions occur. Soil and vegetation samples will be collected prior to the first retort burn (1980) and annually thereafter and stored for future trace metal analysis. If source emission monitoring indicates that significant trace metal emissions are occurring, these stored samples will be analyzed to determine trace metal content. Although projected gaseous and particulate emissions are not expected to contain trace metals, source emission monitoring is designed to determine if trace metals do occur in emissions. Soil sampling is conducted concurrently with the air quality emissions monitoring program.

2. Methods

The methods to be followed for collection of the soils trace metal data were described in RBOSC MDP Monitoring Report 1.

3. Results

No results are available. The first soil sample collection is scheduled for August of 1979 (Table 3-1).

B. Conductivity

During the Commercial Phase, cooling towers will be operated in conjunction with surface retorting. Salt drift may result from this operation. An evaluation was made of the present conductivity levels in the Tract C-a soils during the baseline studies; saline soils were present.

1. Objectives

The soil conductivity studies are designed to detect any significant changes in soil salinity or conductivity levels which might result from an accumulation of salt drift from the towers. These data will be evaluated to determine if any such soil salinity changes are detrimental to plant growth.

TABLE 3-1. TERRESTRIAL STUDIES MONITORING SCHEDULE

Parameter	Start Date	Frequency
Trace Metals (Collection & Storage of soils & vegetation samples)	Aug. 1979	Annually
Soil Conductivity Studies	Aug. 1981	Annually
Vegetation Mapping	May 1978	Annually
Range Productivity & Utilization	April 1978 (establish plots)	Annually (in Sept.)
Browse Condition & Utilization	May 1978	Annually
Mule Deer Density Studies	Sept. 1977	Semi-annually (May,Sept.)
Feral Horse Abundance	Jan. 1978	Annually
Threatened & Endangered Species	Nov. 1978	Opportunistic

2. Methods

The methods to be followed for collection of soil conductivity data were described in RBOSC MDP Monitoring Report 1.

3. Results

No results are available. The first soil sample collection is scheduled for August of 1981 (Table 3-1).

3.2 VEGETATION, RANGE AND BROWSE

A. Vegetation

1. Objectives

Construction and operation at Tract C-a may affect the total distribution of vegetation types as a result of dewatering and reinjection. The vegetation study is designed to monitor the distribution of vegetation on Tract C-a and adjacent areas to determine large-scale changes resulting from MDP development.

2. Methods

The methods to be followed for collection of these data were described in RBOSC MDP Monitoring Report 1.

3. Results

Color and color infrared (CIR) aerial photography (1 inch = 2,000 feet scale) was taken of Tract C-a and the area within a five-mile radius on August 3 and October 10, 1978, respectively. A comparison of the 1978 aerial photography to the RBOSC vegetation map (RBOSP 1977a) indicates that most changes are directly related to the recent industrial development in the area (Figure 3-1, enclosed in pocket). Disturbances resulting from industrial development include RBOSC's MDP construction activities, Munson's natural gas drilling operations on 84 Mesa, Munson gas well and piping yard on

Airplane Ridge, and the County gravel pit near County Road 24. An evaluation of the CIR photography did not detect any changes in the distribution of vegetation types and did not identify any major vegetation stress conditions. Ground observations indicate that small areas of sagebrush are being affected downstream of MDP operations along Corral Gulch. Presumably this reduction in vegetation abundance is due to the increased water level in Corral Gulch resulting from surface water disposal. No indication of this vegetation change was evident on the CIR photography. This area will be closely monitored in the future to determine any long-term changes.

B. Range

1. Objectives

MDP activities on Tract C-a may affect the range conditions on and near tract. These studies are designed to provide information on vegetative production which can be used to compare range productivity before and during modular development. Because the potential impacts are projected to be localized, the range studies focus on areas on Tract C-a that are adjacent to MDP activities and that were previously used for grazing.

2. Methods

The methods followed for collection of range data were described in RBOSC MDP Monitoring Reports 1 and 2. However, cushion plants, e.g., Phlox hoodii were not harvested during 1978 since such species do not provide available forage.

3. Results

The range production and utilization data obtained during September of 1978 (Appendix 3-2.1) are summarized in Table 3-2 for mixed brush, pinyon-juniper, and upland sagebrush. Table 3-3 presents the revised range production

TABLE 3-2. RANGE PRODUCTION (LBS/ACRE) AND UTILIZATION (%) ESTIMATES OBTAINED IN SEPTEMBER 1978 ON AND NEAR RBOSC TRACT C-a

	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Prod.	Util.	Prod.	Util.	Prod.	Util.
Grasses						
Agropyron dasystachyum					19.6	
Agropyron sp.	38.0		1.6			
Bromus tectorum	0.7		2.3		8.3	
Carex sp.					0.2	
Koeleria gracilis	14.0		0.3		7.5	
Oryzopsis hymenoides	16.4		4.6		4.9	
Poa sp.	15.5		7.5		11.7	
Sitanion hystrix			2.0		8.4	
Stipa sp.	0.7		0.2		9.1	
Unknown grasses	0.4		0.9		0.1	
Total Grasses	85.6 (44.1)	26	24.4 (11.5)	48	70.0 (24.0)	39
Forbs						
Achillea lanulosa	0.6					
Antennaria sp.	2.1				1.1	
Arabis sp.			0.1			
Arenaria fendleri			0.2		0.1	
Artemisia ludoviciana	1.5					
Astragalus chamaeleuce	0.4		<0.1		0.1	
Astragalus convallatius	2.9		0.1		0.5	
Astragalus sp.	0.4				0.7	
Balsamorhiza sagittata	2.6		2.8		0.5	
Castilleja sp.	<0.1					
Chaenactis douglasii	0.1					
Chenopodium album			0.5		0.2	
Cleome serrulata					11.3	
Comandra umbellatum	14.9				2.2	
Cryptantha sericea	1.7		1.3		2.2	
Eriogonum alatum			0.1		0.2	
Eriogonum umbellatum	12.2		0.1		0.4	
Eriogonum sp.	1.0		2.9			
Gilia aggregata	0.6				0.1	
Haplopappus nuttallii	1.9		3.8		1.5	
Hedysarum boreale	17.6				2.4	
Heterotheca villosa	3.5		0.2		1.2	
Hymenoxys acaulis	1.6					
Lappula occidentalis					1.2	
Linum lewisii	2.6				0.2	
Lupine sp.	7.5				5.2	

TABLE 3-2 . (Continued)

	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Prod.	Util.	Prod.	Util.	Prod.	Util.
Machaeranthera canescens	0.5		0.1			
Mahonia repens	5.8		0.3			
Penstemon sp.	1.4				0.2	
Phlox longifolia	4.1				1.2	
Physaria floribunda	< 0.1				0.1	
Salsola kali	0.3					
Senecio multilobatus	0.8					
Senecio sp.	2.4		0.1		3.1	
Sphaeralcea coccinea	0.7		0.1		2.0	
Thelypodiopsis elegans	0.5		0.7		0.8	
Unknown forbs	6.0		0.4		1.7	
Total Forbs	99.0 (58.6)	29	14.0 (17.9)	42	40.1 (33.5)	47
TOTAL	184.7		38.4		110.1	

*Numbers in parentheses are standard deviation(s).

TABLE 3-3. REVISED RANGE PRODUCTION (LBS/ACRE) AND UTILIZATION (%) ESTIMATES OBTAINED IN AUGUST 1977 ON AND NEAR RBOSC TRACT C-a.

	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Prod.	Util.	Prod.	Util.	Prod.	Util.
Antennaria sp.			0.2		0.2	
Astragalus sp.	1.4		<0.1			
Chaenactis sp.	<0.1					
Chenopodium sp.	0.9				1.2	
Comandra umbellatum	20.1					
Cryptantha sericea	0.2		0.4		0.4	
Eriogonum sp.	10.3				0.1	
E. lonchophyllum					0.3	
E. umbellatum	5.5				0.5	
Erysimum asperum	0.1					
Haplopappus nuttallii	11.5		1.8		0.2	
Hedysarum boreale	3.4					
Hymenoxys acaulis	7.0				<0.1	
Ipomopsis aggregata	0.2		<0.1		0.1	
Linum lewisii	1.2					
Lithospermum ruderale	1.2					
Penstemon sp.	0.3		0.1		0.4	
Phlox sp.	15.8		0.3		0.4	
P. hoodii			3.8		6.2	
Physaria floribunda	0.9		< 0.1		0.8	
Senecio multilobatus	0.4		0.1		0.2	
Sisymbrium linifolium					0.1	
Sphaeralcea coccinea	1.3		0.2		2.3	
Taraxacum officinale	0.1					
Unknown Legume	10.5		0.4		0.1	
Other Forbs	5.0		1.1		1.8	
Total Forbs	97.5 (29.7)	47	8.4 (8.1)	31	15.5 (13.2)	23
Total Grass	147.3 (92.0)	65	59.4 (29.0)	50	95.4 (67.7)	58
TOTAL	244.8		67.8		110.9	

*Numbers in parentheses are standard deviation(s).

estimates for 1977.[1] A comparison of range production and utilization estimates obtained in 1975, 1977 and 1978 is presented in Table 3-4.

a. Mixed Brush - Mixed brush had the highest production and the lowest utilization of the three vegetation types sampled during 1978 (Table 3-4). Grass and forb production were approximately equal. The dominant species were grasses although sweetvetch (Hedysarum boreale), bastard toadflax (Comandra umbellatum), and sulphur flower (Eriogonum umbellatum) were common (Table 3-2). Production measured during 1978 is lower than that estimated during 1975 or 1977. Grass and forbs were equally utilized during 1978 but overall utilization was approximately half of that recorded during 1977 (Table 3-4).

b. Pinyon-Juniper - Pinyon-juniper had the lowest production and the highest utilization of the three vegetation types sampled during 1978 (Table 3-4). Grasses represent the largest portion of total production. The dominant grasses included bluegrass (Poa sp.) and Indian ricegrass (Oryzopsis hymenoides); dominant forbs were goldenweed (Haplopappus nuttallii), buckwheat (Eriogonum sp.) and arrowleaf balsam root (Balsamorhiza sagittata). Grasses contributed the greatest portion (63%) of the production (38 lbs/acre) in this type (Table 3-3). Production in the pinyon-juniper during 1978 was the lowest of the three years for which data are available (Table 3-4); utilization was the highest during 1978. Grasses were eaten approximately equally during 1977 and 1978 but utilization of forbs increased during 1978.

c. Upland Sagebrush - Forage production in upland sagebrush was midway between that estimated for mixed brush and pinyon-juniper during 1978 (Table 3-4). Overall utilization was similar to estimates for pinyon-juniper. Grasses contributed approximately 64 percent of the total production (110 lbs/acre) in upland sagebrush (Table 3-3). The dominant grasses were thickspike wheatgrass (Agropyron dasystachyum) and bluegrass. The most abundant forbs were beeplant (Cleome serrulata) and lupine (Lupinus sp.). The 1978

[1] Table 5 in the Second Semi-Annual Report for the RBOSC Interim Studies (1977b) is mislabeled. The data presented in Table 5 are estimates of standing biomass and do not represent production values.

TABLE 3-4. COMPARISON OF RANGE PRODUCTION AND UTILIZATION ESTIMATES OBTAINED IN 1975, 1977 and 1978 ON AND NEAR TRACT C-a.[1]

Vegetation Type	Production (dry weight) (lbs/acre)			Utilization (%)		
	1975	1977	1978	1975	1977	1978
Mixed Brush						
Grasses		147	86		65	26
Forbs		98	99		47	29
Total	207	245	185	38	56[2]	28[2]
Pinyon-Juniper						
Grasses		59	24		50	48
Forbs		8	14		31	42
Total	101	67	38	32	41[2]	45[2]
Upland Sagebrush						
Grasses		95	70		58	39
Forbs		16	40		23	47
Total	269	111	110	8	41[2]	43[2]

[1]The comparison is for the vegetation type in general. The same transects were not sampled during each period nor was the sample size equal.

[2]An average of grass and forb utilization.

production and utilization in upland sagebrush was approximately equal to that estimated in 1977. Production was considerably less than that measured in 1976 while utilization was approximately five times that estimated in 1976.

In general, production substantially decreased from 1975 to 1977-1978; explanations for this decrease are not apparent. The 1977 and 1978 production levels were more similar although 1977 estimates were generally higher. The higher 1977 estimates are probably related to the late summer rains which occurred in late July and August of 1977 and could have affected the production measured in August. Precipitation during the 1978 growing season was concentrated in May and June; the effects of Spring precipitation were probably negated by the time of the September sampling.

d. Statistical Analyses - The range studies are designed to test differences between the pre-development conditions with those during development. Because nine of the sampling locations were relocated during the first year of the MDP monitoring program (1978), comparisons between years are not possible during 1978.

A comparison between protected (exclosures) and unprotected plots was performed (Table 3-5). Significant differences at the 0.5 level exist between protected and unprotected plots for grasses in each of three vegetation types. There are no significant differences for forbs. These results suggest that grasses were more important as forage than were the forbs.

Adequate sample size for the RBOSC range studies was calculated using the September 1978 range data (Table 3-6). Adequate sampling size is assumed to be a detection level of $\pm$ 20 percent of the mean 80 percent of the time. The results indicate that grasses are adequately sampled in all three vegetation types by the present range study design. Forbs are adequately sampled in mixed brush. The large number of plots required for an adequate sample for forbs in pinyon-juniper and upland sagebrush (114 to 527 plots) appears excessive. The large sample size is probably related to sparseness and the distribution pattern of forbs in these two types. Therefore, the present sampling design has not been changed. Additional evaluation of sampling size will be made as more data are available.

TABLE 3-5. A COMPARISON OF PROTECTED AND UNPROTECTED RANGE PLOTS IN MIXED BRUSH, PINYON-JUNIPER AND UPLAND SAGEBRUSH ON OR NEAR TRACT C-a DURING SEPTEMBER 1978.

Growth Form	Vegetation Type	Protected			Unprotected			t-test
		$\bar{x}$	s	n	$\bar{x}$	s	n	
Grasses	Mixed Brush	91.2	72.6	50	61.2	62.8	50	.05
	Pinyon-Juniper	24.1	30.0	50	11.9	10.2	50	.05
	Upland Sagebrush	87.8	103.3	48[1]	43.0	40.0	52[1]	.05
Forbs	Mixed Brush	94.1	97.2	50	70.2	80.2	50	NS
	Pinyon-Juniper	15.5	46.2	50	9.9	28.6	50	NS
	Upland Sagebrush	33.2	59.7	48[1]	25.3	97.8	52[1]	NS

Legend:

$\bar{x}$ = Mean production
s = Standard deviation
n = Sample number
NS = Non-significant

[1]Sample size was unequal due to disturbance to two exclosures during the growing season.

TABLE 3-6. ESTIMATES OF ADEQUATE SAMPLE SIZE[1] FOR RANGE STUDIES BASED ON SEPTEMBER 1978 PRODUCTION DATA

Vegetation Type	Protected	Unprotected
Mixed Brush		
Grasses	22	37
Forbs	38	46
Pinyon-Juniper		
Grasses	55	26
Forbs	313	294
Upland Sagebrush		
Grasses	49	31
Forbs	114	527

[1]Wyoming Department of Environmental Quality (1978)

$$N \geq \frac{2\,(s\,z)^2}{(d\,\bar{x})^2}$$

n = minimum sample size
s = standard deviation
z = z statistic = .84
d = detection level = .2
$\bar{x}$ = sample mean

C. Browse

1. Objectives

Tract C-a development may reduce browse availability and therefore affect animal distribution in the vicinity of Tract C-a. The browse condition and utilization studies are designed to provide browse use information for areas adjacent to Tract C-a development.

2. Methods

The methods followed for collection of browse data were described in RBOSC MDP Monitoring Reports 1 and 2.

3. Results

Browse and utilization data were collected in May 1978 and the results presented in RBOSC MDP Monitoring Report 2. A summary of the browse utilization results for Spring 1976, 1977 and 1978 is presented in Table 3-7.

TABLE 3-7. AVERAGE UTILIZATION (% Utilization)[1] IN THREE VEGETATION TYPES DURING APRIL 1976, MAY 1977 AND MAY 1978 ON AND NEAR TRACT C-a.

	April 1976	May 1977	May 1978
Mixed Brush	12	17	7
Pinyon-Juniper	27	24	31
Upland Sagebrush		6	25

[1]The comparison is for the habitat type in general; the same transects were not sampled during each period nor was the sample size equal.

During the first year of MDP operations (1978), pinyon-juniper and sagebrush had the highest utilization while utilization in mixed brush decreased from 1976 and 1977. Utilization in the sagebrush type was substantially higher than the utilization measured during 1977. A comparison of the individual transects (RBOSC 1978b) indicated that the increase is utilization was probably related to feral horse use. Therefore, it is doubtful that MDP activities affected utilization in the sagebrush area

Adequate sampling size for the RBOSC browse studies was determined using the May 1978 browse data (Table 3-8). An adequate sample size is assumed to be a detection of $\pm$ 10 percent of the mean 80 percent of the time. Shrub species were generally adequately sampled during May 1978 if the sample size was greater than 15. Exceptions to this included big sagebrush (Artemisia tridentata), pinyon pine (Pinus edulis), and bitterbrush (Purshia tridentata) in the pinyon-juniper type. The large adequate sample size required for big sagebrush is related to the variability in utilization. This variation may reflect the difference in palatibility which is known to exist for this species. Pinyon pine requires a large sample size as a result of the variation in availability; thus; utilization of pinyon pine is not uniform among individuals. Overall, it appears that the browse study is designed to adequately detect any changes in browse utilization which might result from RBOSC MDP activities. Sample size will be evaluated periodically.

TABLE 3-8. ESTIMATES OF ADEQUATE SAMPLE SIZE[1] FOR BROWSE STUDIES BASED ON MAY 1978 BROWSE DATA.

Plant Species	Vegetation Type	1978 N	$\bar{x}$	s	Adequate Sample Size
AME UTA	MB	125	8.8	10.9	20
	SB	11[2]	12.3	21.9	77
	PJ	2[2]	25.0	35.4	200
ART TRI	MB	56	6.3	17.8	51
	SB	186	26.6	31.4	155
	PJ	90[2]	23.3	31.0	155
CER MON	MB	13[2]	13.1	11.5	22
	PJ	15	97.3	5.6	7
JUN OST	PJ	28	0.8	3.8	4
PIN EDU	MB	6[2]	2.5	4.2	7
	PJ	45[2]	14.2	27.1	118
PUR TRI	PJ	31[2]	79.2	24.9	100
SYM ORE	MB	38	1.5	3.8	4
	PJ	4[2]	5.0	10.0	18

Legend:

AME UTA = Amelanchier utahensis
ART TRI = Artemisia tridentata
CER MON = Cercocarpus montanus
JUN OST = Juniperus osteosperma
PIN EDU = Pinus edulis
PUR TRI = Purshia tridentata
SYM ORE = Symphoricarpos oreophilus

MB = Mixed Brush
PJ = Pinyon-Juniper
SB = Upland Sagebrush
N = 1978 Sample size
$\bar{x}$ = Sample mean
s = Standard deviation

[1] $N \geq 2 \left(\frac{\delta}{\theta}\right)^2 \left(t_{\alpha\{\gamma\}} + t_{2(1-\rho)\{\gamma\}}\right)^2$

N = Minimum sample size
δ = Standard deviation
θ = Detection level
γ = Degrees of freedom
α = .05
ρ = 80%
[2] = Not adequately sampled during May 1978.

3.3 Fauna

A. Mule Deer

1. Objectives and Rationale

Mule deer are the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek Basin mule deer herd is one of the largest migratory mule deer herds in North America. Tract C-a is within the Piceance Creek Basin and Colorado Division of Wildlife's (CDOW) Game Management Unit 22.

Moderate numbers of mule deer occur on Tract C-a during fall and spring migration periods and during mild winters; at other times mule deer are relatively uncommon on the tract. Consideration of the possible effects of Tract C-a oil shale development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan.

The objectives of RBOSC's mule deer monitoring program are to obtain an index of mule deer density in a 9 x 9 mile (81 sq mi) study area centered on Tract C-a, to compare indices of mule deer density from the study area with those from Game Management Unit 22, and, if possible, to compare differences in mule deer densities within various portions of the study area.

2. Methods

Mule deer density estimates can be calculated from pellet-group density data as mule deer defecate a more or less uniform number of times daily (Neff 1968). The number of pellet-groups per unit area, days of use by deer, and deer per unit area in the Tract C-a study area are determined as described by Overton (1971). The methods followed for collection of these data were described in RBOSC MDP Monitoring Report 1.

3. Results and Discussion

Mule deer pellet groups were counted in 20 plots in each of seven 160-acre sample units in each of the nine square blocks comprising the Tract C-a mule deer study area. Summary pellet group information from the Spring, and Fall, 1978 sampling periods are presented in Table 3-9. Detailed data on each plot for Fall 1978 are presented in computer print-out format in Appendices 3.3-1. Summary statistical analysis of winter data is presented as Appendix 3.3-2.

Deer enter the study area in the Fall generally as a result of increasing snow depth or worsening weather forcing them to abandon summer ranges at higher elevation. Due to different individual tolerances to winter conditions the deer leave the higher elevation and enter the study area over a variable period of time. Depending on weather conditions, migratory deer begin arriving in the study area in late October. The majority of the deer reach the lower elevation by December 1. Spring migrations from the study area are also dependent on weather conditions but the movements back to higher elevations generally occur over a shorter period of time once a migration is initiated. The majority of the deer leave the study area by April 1.

Since the exact number of winter deer use days are unknown for the study area, deer density indices are reported for a series of day totals. Few deer are in the study area during the summer period. Pellet counts are conducted following that period to obtain a qualitative index of deer numbers during the summer and to clear the plots for the winter accumulation period. Therefore, summer pellet group data are not compared statistically. Deer density for the summer is computed using the number of days between the Spring and Fall sampling periods.

The CDOW conducts an annual mule deer pellet group count on 54 square mile sample units randomly selected throughout the 606 square mile Piceance Basin (Freddy 1978). The CDOW counts new pellet groups on 20 1/1000 hectare plots in each sample unit in a manner similar to the RBOSC mule deer study. The same total area (20/1000 hectares) is examined per sample unit by both methods. According to the CDOW, RBOSC Tract C-a is in a low to medium deer density area of the Piceance Basin.

TABLE 3-9 . ESTIMATED MULE DEER PER SQUARE MILE BY BLOCK OF THE RBOSC STUDY AREA 1977-78[1]

	WINTER PERIOD DAYS OF DEER USE[2]					SUMMER PERIOD[3]
Block	120	150	180	210	Average	
1	83.0	66.4	55.3	47.4	63.0	24.9
2	61.7	49.3	41.1	35.2	46.8	28.5
3	83.0	66.4	55.3	47.4	63.0	22.5
4	56.9	45.5	37.9	32.5	43.2	13.0
5	131.6	105.3	87.8	75.2	100.0	17.8
6	84.2	67.4	56.1	48.1	64.0	11.9
7	51.0	40.8	34.0	29.1	38.7	7.1
8	40.3	32.3	26.9	23.0	30.6	7.1
9	11.9	9.5	7.9	6.8	9.0	4.7
Entire Study Area	67.1	53.7	44.7	38.3	50.9	15.3

[1]Based on a defecation rate of 13 pellet groups per deer per day.

[2]The exact number of days deer were in the study area is unknown; therefore, computations were made using various days of deer use.

[3]Based on 120 days in the summer accumulation period.

The average number of pellet groups counted by the CDOW per 20 plots (sq mi sample unit) for the Piceance Basin in 1977-78 was 15.95 ± 2.06 at the 10 percent level of confidence. This figure extrapolated to give deer density for the Piceance Basin produces a higher estimate of population than that obtained by an aerial census (Freddy 1978). The average number of pellet groups counted per 20 plot sample unit on the RBOSC study area for 1977-78 was 8.08 ± 1.12 at the 10 percent level of confidence (See Appendix 3.3-2). Therefore, the density of mule deer, as estimated by pellet group counts, on the RBOSC study area appears to fall within the expected range for that portion of the Piciance Basin.

Based on the variability of pellet groups among sample units for the 1977-78 season, the RBOSC mule deer study sampling design estimates the density of deer pellet groups within ± 14 percent of the mean 90 percent of the time. This precision agrees favorably with the precision achieved by the CDOW sampling design.

B. Feral Horses

1. Objectives and Rationale

Feral horses occur on and in the vicinity of Tract C-a. These horses are protected under federal law and are under the jurisdiction of the BLM. Feral horses compete with cattle and, to a lesser extent, with mule deer for available forage. The objective of feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSC study area (e.e., same study area as for mule deer).

2. Methods

The methods followed for collection of data on feral horses were described in RBOSC MDP Monitoring Report 1.

3. Results and Discussion

Feral horses may be found throughout the RBOSC study area. Movements of individual bands are generally restricted to established territories within fenced areas. Band numbers and sizes fluctuate with seasons as determined by changing grazing conditions and the abilities of individual studs to obtain and maintain a band. General observations of feral horses are made throughout the year by environmental personnel on tract. Any abnormal observations are reported.

The annual feral horse census, representing a count of all horses in the study area at one time and, thereby eliminating duplication, is taken from aircraft during January. This census is done in consultation with personnel of the Bureau of Land Management and yields an index to the numbers of horses in the study area. The January 1978 feral forse census was reported the RBOSC MDP monitoring Report 2. Results of the January 1979 feral horse census will be reported in the RBOSC MDP Monitoring Report 4.

Feral horses on the Tract C-a study area were counted from a fixed-wing aircraft in January, 1978. Seven bands of horses totaling 53 individuals were observed in the study area. BLM personnel estimate that approximately 60 percent of the horses in areas with topography and vegetation cover similar to that of the study area are observed from fixed-wing aircraft. The total number of horses on the Tract C-a study area during January, 1978 may have been between 80 and 100.

C. Threatened and Endangered Species

Baseline and interim monitoring studies indicate that Tract C-a does not provide critical habitat for any state or federally endangered species. Greater sandhill cranes were observed during the baseline studies on 84 Mesa, at the Stake Springs impoundment, and east of 84 Ranch. One whooping crane was sighted east of 84 Ranch. Neither of these species was observed during the reporting period.

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SECTION 4

AQUATIC STUDIES

From October 1974 through September 1976, aquatic biological baseline data were collected from the surface waters of Tract C-a, from Yellow Creek (near its confluence with the White River),and from the White River. A total of 35 sampling sites was included in the Baseline Monitoring Program which was designed to characterize the aquatic biota and their habitats. Sampling intensity was greatest during the Spring, Summer and Fall when biological activity was highest. During the baseline studies, the species composition, relative abundance and distribution of phytoplankton, zooplankton, aquatic macrophytes, periphyton, benthos, and fish were determined. In addition, studies of age, growth, condition, and reproduction of fishes of the White River and Yellow Creek were conducted.

The RBOSC aquatic baseline studies indicated that phytoplankton, zooplankton, and aquatic macrophytes play relatively unimportant roles in the aquatic ecosystems of the area. The baseline studies also revealed that periphyton are the major primary producers and that benthic macroinvertebrates are the primary aquatic consumers on the tract. Fish occurred only in Yellow Creek and the White River. The distribution of aquatic macrophytes was limited to a few pond habitats.

From September 1976 to August 1977, RBOSC conducted an interim aquatic biological monitoring program. The completeness of the baseline aquatic data precluded the need to collect additional data on all baseline parameters during the interim monitoring period. There was, however, a need to monitor important elements of the aquatic ecosystem during this interim period to identify and characterize any major changes which might occur during that time. Thus, during the interim period, samples of periphyton and benthos were collected and physical measurements were taken during the late fall and in the spring at three of the sampling sites utilized during baseline studies (Station 13, 20, and 29) (Figure 4-1).

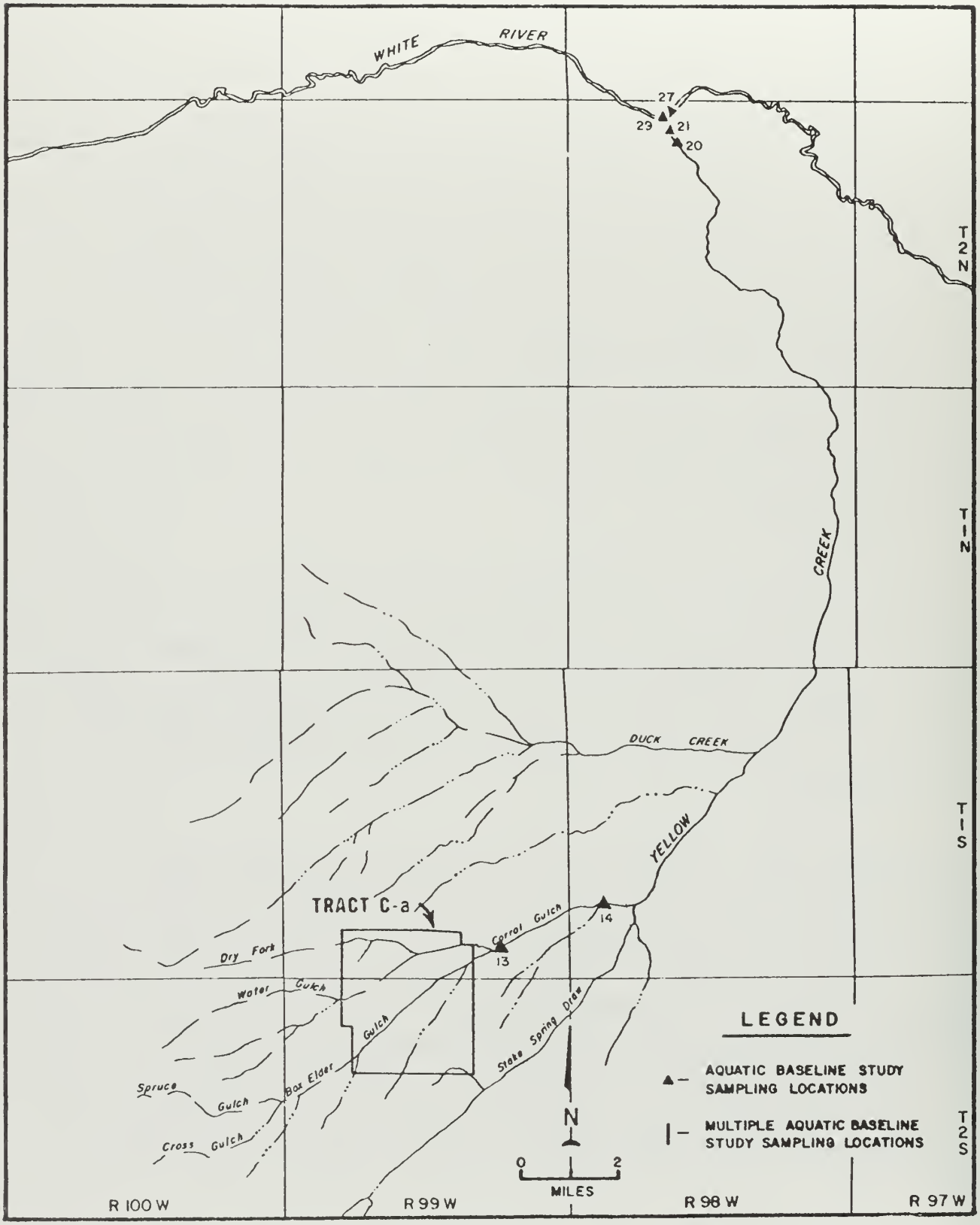

Figure 4-1. Locations of Aquatic Ecology MDP Sampling Sites

In October 1977, RBOSC initiated the MDP Aquatic Monitoring Program. This program was based upon a detailed analysis of the aquatic baseline data and upon projected potential impacts of modular development on Tract C-a.

A total of six sampling sites has been chosen for the MDP Aquatic Monitoring Program (Figure 4-1). These sampling sites are representative of the type of aquatic habitats which occur on or near Tract C-a and include:

- Station 13 (spring-brook habitat) at the USGS gaging station in Corral Gulch (east),
- Station 14 (pond habitat) in Corral Gulch (east),
- Station 20 (spring-brook habitat) at the USGS gaging station on Yellow Creek,
- Station 21 (spring-brook habitat) on Yellow Creek below the USGS gaging station, and
- Station 27 and 29 (White River back channel habitats) near the confluence of Yellow Creek with the White River.

Sampling was conducted during April, June, July, August, and October of 1978. These months coincided with the sampling periods for the baseline studies. This report contains the results for the 1978 MDP aquatic sampling program and includes the data collected during the October 1977 sampling period, and comparisons with data collected during the baseline (1974-1976) period.

A. Physical Measurements

1. Objectives

The objectives of taking physical measurements during the MDP Aquatic Monitoring studies are to monitor selected physical characteristics of the stream at each sampling site and to relate these characteristics to baseline chemical and biological conditions. The physical measurement program includes those chemical parameters which are measured in conjunction with field sampling.

2. Methods

Methods for the physical measurements are described in the RBOSC MDP Monitoring Report 1 (1977).

3. Results and Discussion

The physical measurement at the six monitoring stations for the MDP were quite similar to the baseline conditions (Table 4-1). A significant increase in the volume of flow occurred at Stations 13 and 14 (Figure 4-1) due to the operational discharge of water into Corral Gulch. The higher flows resulted in an increase in the width, depth and velocity at these two station but did not significantly affect the other physical parameters.

At Stations 20 and 21 on Yellow Creek, the alkalinity, conductivity, and pH were somewhat higher and dissolved oxygen was slightly lower for the period from October 1977-October 1978 than for the baseline period. This is probably related to the greater influence of groundwater on streamflow due to the drought conditions that existed during 1977 and the drier-than-average conditions that occurred during the Summer of 1978.

A comparison of the two White River Stations (27 and 29) for the MDP and baseline periods showed no apparent differences in the physical measurements.

TABLE 4-1 COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF STREAMS FROM RBOSC MDP STUDIES (1977-1978) AND RBOSC BASELINE STUDIES (1974-1976)

STATION 13

Parameter	Date	Baseline										MDP					
		10-11/74	4/75	5-6/75	7-8/75	8-9/75	10/75	4/76	5-6/76	7-8/76	8-9/76	10/77	4/78	6/78	7/78	8/78	10/78
Water Temperature (^{o}C)		10	9	20	18	11	13	13	18	15	15	19	17	13	15	12	11
Conductivity (μmhos/cm)		1,200	1,730	1,500	1,200	1,300	1,200	1,150	1,100	1,200	1,100	1200	1500	1500	1400	1600	1800
Dissolved Oxygen (mg/l)		8.9	5.2	5.6	6.2	7.6	8.4	7.8	6.1	7.1	7.0	8.0	5.1	6.4	6.6	7.4	7.9
Total Alkalinity (mg/l)		410	716	646	396	419	421	435	379	381	397	401	584	410	302	482	496
pH		7.8	8.3	8.3	7.5	7.6	7.8	7.5	7.8	8.0	7.9	7.8	8.3	7.8	8.1	8.0	7.8
Turbidity (JTU)		2	>1,000	450	6	1	1	>1	163	4	12	-	60	520	-	8.8	1.5
Substrate		Sa,Gr	Gr,Si	Gr,Sa,Si	Gr,Sa	Gr,Sa	Gr,Sa	Gr,Sa	Gr,Sa	Gr,Sa	Gr,Sa	Gr	Gr	Gr,Sa	Gr,Sa	Gr	Gr
Width (ft)		3.0	3.0	4.2	2.8	2.5	2.0	4.0	2.5	3.0	3.0	3.5	3.5	3.0	5.0	4.0	4.5
Depth (in)		1,1,1.5	3	4	3	4	3	4	5	3	2	2	6	6	6	4	7
Velocity (fps)		0.5	1.0	1.7	2.0	1.1	1.9	1.4	2.1	2.1	1.4	0.7	2.0	2.9	2.3	1.7	2.0

TABLE 4-1 COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF STREAMS FROM RBOSC MDP STUDIES (1977-1978) AND RBOSC BASELINE STUDIES (1974-1976)

STATION 14

		Baseline										MDP					
Parameter	Date	10-11/74	4/75	5-6/75	7-8/75	8-9/75	10/75	4/76	5-6/76	7-8/76	8-9/76	10/77	4/78	6/78	7/78	8/78	10/78
Water Temperature (^{o}C)		8	5	18	19	12	14	9	24	23	17	8	16	16	14	11	6
Conductivity (μmhos/cm)		1,800	1,800	1,550	2,000	1,850	1,800	1,750	1,750	1,700	1,200	1700	1400	1600	1700	1800	1850
Dissolved Oxygen (mg/l)		13.4	11.1	12.6	12.9	7.4	14.4	9.7	12.3	8.5	8.5	9.8	10.1	8.6	9.4	10.1	9.0
Total Alkalinity (mg/l)		454	492	485	532	564	520	546	510	528	542	521	424	-	530	495	510
pH		8.2	8.4	8.2	7.9	7.9	8.3	7.9	8.2	8.0	8.1	7.7	8.4	8.4	8.1	8.2	7.6
Turbidity (JTU)		1	9	2	7	2	4	3	2	14	<1	-	25	-	-	1.3	1.0
Substrate		Cl	Si	Sa,Cl	Sa,Si	Si	Si	Sa	Gr,Sa	Sa	Sa	Sa,De	Sa,Si,De	Sa	Gr,Si	Sa,Si	Si,Gr
Width (ft)		1.0	0.3	2.5	3.6	2.4	3.0	1.5	1.5	0.3	0.3	0.3	0.5	3.0	2.0	3.0	4.5
Depth (in)		6	2	3-6	3-6	4	6	4	6	3	2	2	6	9	6	12	9
Velocity (fps)		1.3	0.5	0.0	0.0	1.0	0.4	1.2	1.1	1.5	1.5	0.7	1.0	1.9	1.3	0.6	1.3

TABLE 4-1. COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF STREAMS FROM RBOSC MDP STUDIES (1977-1978) AND RBOSC BASELINE STUDIES (1974-1976)

STATION 20

		Baseline										MDP					
Parameter	Date	10-11/74	4/75	5-6/75	7-8/75	8-9/75	10/75	4/76	5-6/76	7-8/76	8-9/76	10/77	4/78	6/78	7/78	8/78	10/78
Water Temperature (^{o}C)		7	14	23	19	25	11	19	22	31	11	11	16	25	23	24	11
Conductivity (μmhos/cm)		3,000	3,700	3,600	3,800	3,300	3,850	4,000	4,200	4,500	4,000	4100	4200	4800	5000	4600	5000
Dissolved Oxygen (mg/l)		8.7	9.4	8.2	8.7	7.2	10.6	9.4	6.3	8.6	7.4	7.1	8.2	6.5	7.4	7.4	7.4
Total Alkalinity (mg/l)		1,149	1,291	1,393	1,375	1,650	1,485	1,632	1,740	1,664	1,456	1658	1444	-	2700	2286	1732
pH		8.5	8.6	8.3	8.8	8.7	8.7	8.7	8.0	8.0	8.7	8.6	8.1	8.8	8.9	9.2	8.6
Turbidity (JTU)		12	81	7	7	28	13	110	12	3	58	-	75	-	-	5	2
Substrate		Gr	Gr,Si,Sa	Gr,Sa	Sa,Si	Si,Gr,Sa	Gr,Sa	Gr	Gr,Sa	Gr,Sa	Gr	Gr,Sa	Co,Gr	Gr,Sa	Gr,Sa	Gr,Si	Gr,Si
Width (ft)		2.3	1.0	0.8	3-6	5.4	3.3	5.0	3.0	0.8	6.0	1.8	3.0	2.0	1.0	2.0	5.5
Depth (in)		4.5	3.5	4	36	3	3	4	5	3	3	0.7	4	5	5	3	3.5
Velocity (fps)		1.7	1.3	1.4	1.4	0.7	1.3	1.1	1.8	1.1	1.2	1.9	1.5	1.3	1.4	0.7	0.9

TABLE 4-1 COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF STREAMS FROM RBOSC MOP STUDIES (1977-1978) AND RBOSC BASELINE STUDIES (1974 1976)

STATION 21

		Baseline										MOP					
Parameter	Date	10-11/74	4/75	5-6/75	7-8/75	8-9/75	10/75	4/76	5-6/76	7-8/76	8-9/76	10/77	4/78	6/78	7/78	8/78	10/78
Water Temperature (^{o}C)		8	14	18	19	24	8	18	17	28	11	12	13	20	23	22	11
Conductivity (µmhos/cm)		3,000	3,700	3,400	3,900	3,900	3,880	3,900	3,900	4,000	4,000	4100	4200	4900	4800	3800	5000
Oissolved Oxygen (mg/l)		9.9	8.9	9.2	8.1	8.8	10.7	10.2	7.4	10.2	7.6	7.9	6.9	6.7	7.5	5.9	7.2
Total Alkalinity (mg/l)		1,244	1,306	1,449	1,451	1,651	1,567	1,658	1,660	1,558	1,600	1650	1532	-	1404	2190	2058
pH		8.6	8.6	8.3	8.7	8.7	8.7	8.7	8.5	8.0	8.7	8.8	8.7	8.9	9.0	9.0	8.6
Turbidity (JTU)		2	68	3	8	25	20	100	14	14	176	-	75	-	-	10	1.5
Substrate		Sa,Gr	Gr,Si	Gr,Sa	Gr,Sa	Gr,Sa	Gr,Sa	Gr	Gr,Sa	Gr,Si	Gr,Sa,Si	Gr,	Gr,Sa	Gr,Sa	Gr,Sa	Sa,Si	Gr
Width (ft)		3.0	5.4	5.0	4.5	2.7	3.3	6.0	12.0	6.0	1.0	3.0	4.0	3.5	4.0	4.0	4.5
Oepth (in)		1	4	4	3	4	3	4	6	4	5	3	4	6	4	6	2
Velocity (fps)		1.0	1.5	2.3	0.8	1.2	2.0	0.9	0.7	0.6	0.7	1.0	1.0	1.7	0.9	1.0	1.2

TABLE 4-1. COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF STREAMS FROM RBOSC MDP STUDIES (1977-1978) AND RBOSC BASELINE STUDIES (1974-1976)

STATION 27

Parameter	Date	Baseline										MDP					
		10-11/74	4/75	5-6/75	7-8/75	8-9/75	10/75	4/76	5-6/76	7-8/76	8-9/76	10/77	4/78	6/78	7/78	8/78	10/78
Water Temperature (^{o}C)		11	15	12	18	18	9	17	18	20	20	9	9	12	21	19	7
Conductivity (μmhos/cm)		600	850	350	625	825	775	650	550	950	900	900	700		670	700	
		600			625	800	700	640	550	925	900	900	700	550	670	700	800
		700			625	800	700	650	550	925	900	900	700		670	700	
Dissolved Oxygen (mg/l)		12.1	9.8	8.9	8.5	10.9	11.1	10.6	8.0	7.3	9.7	9.6	9.6	8.2	7.9	10.2	10.3
Total Alkalinity (mg/l)		199	207	109	473	206	186	188	157	256	217	214	184	136	180	180	178
pH		8.6	8.5	8.0	8.2	8.6	8.3	8.4	8.0	8.0	8.4	8.3	8.2	8.2	8.7	8.7	8.0
Turbidity (JTU)		7	44	64	28	10	9	32	13	250	4	59	89	54	6	1	0.9
Substrate		Co	Gr,Si	Co	Sa,Si	Co,Sa	Co,Gr	Co	Co	Co,Si	Co,Gr	Co	Co,Si	-	Co,Si	Co	Co,Si
Width(ft)		45	46.5	-	45	45	50	51	56	46	46.5	39	51	-	60	40	52
Depth (in)		2	2		8	20	10	4	8	22	16	1	8	-	8	6	6
		19	23	36	28	12	22	22	26	22	16	10	10	-	10	10	14
		14	4		18	7	22	8	6	18	1	-	4	-	8	6	4
Velocity (fps)		0.4	0.4	1.6	0.4	0.1	0.2	1.2	0.3	0.7	0.9	0.8	1.2	-	2.1	1.9	
		0.4	-	-	-	-	0.6	1.0	1.4	0.8	-	1.1	1.9	-	2.5	2.1	1.4
		0.6	1.2	1.2	1.2	0.9	1.0	0.7	0.7	0.4	-	-	1.4	-	1.7	2.1	

TABLE 4-1 COMPARISON OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF STREAMS FROM RBOSC MDP STUDIES (1977-1978) AND RBOSC BASELINE STUDIES (1974-1976)

STATION 29

		Baseline										MDP					
Parameter	Date	10-11/74	4/75	5-6/75	7-8/75	8-9/75	10/75	4/76	5-6/76	7-8/76	8-9/76	10/77	4/78	6/78	7/78	8/78	10/78
Water Temperature (^{o}C)	b	11	13	12	18	18	9	11	19	20	20	9	9	12	21	19	7
Conductivity (µmhos/cm)		855			750	825	875	730	675	1050	1000	900	700	-	680	700	-
		750	850	400	675	900	760	800	525	1000	950	1050	700	550	680	700	780
		690			625	875	710	1150	500	900	900	1200	700	-	750	750	-
Dissolved Oxygen (mg/l)		10.8	10.1	8.9	8.2	10.2	10.9	10.5	8.1	7.4	9.6	9.7	9.6	8.2	7.5	10.2	10.2
Total Alkalinity (mg/l)		224	207	123	453	230	192	186	175	278	240	269	184	136	183	178	170
pH		8.7	8.4	8.0	8.2	8.6	8.3	8.4	8.1	8.0	8.4	8.1	8.2	8.2	8.7	8.7	8.0
Turbidity (JTU)		8	53	48	20	15	9	43	14	365	20	67	95	7	8	1.2	1.0
Substrate		Co,St	Gr,D	Co	Co,Gr	Co,Sa	Co,Gr	Gr,Sa	Co	Co	Co	Co	Co,Si	-	Co,Gr	Co	Co
Width (ft)		22.6	20.8	-	35	45	26	25	33	24	29.4	26	51	-	22	23	35
Depth (in)		1	1	20	7	7	9	4	3	8	8	2	8	-	8	6	7
		12	11	-	16	12	13	12	16	11	8		10	-	12	16	15
		2	1	20	6	7	8	2	14	5	3	8	4	-	6	4	9
Velocity (fps)		3.4	1.9	5.8	2.1	2.3	4.5	2.8	2.1	1.2	3.3	1.2	1.2	-	2.0	1.4	.8
		-	-	-	-	-	4.5	3.9	3.1	3.2	-		1.9	-	3.4	2.4	.6
		2.3	3.6	3.1	3.1	2.5	1.8	1.9	3.7	2.5		2.3	1.4	-	2.3	1.3	.7

B. Water Quality Measurements

1. Objectives

The objective of this portion of the aquatic monitoring studies is to monitor those chemical characteristics which baseline data analyses (RBOSP Final Environmental Baseline Report 1977) have shown to contribute most to the natural variability in White River water quality and thereby to assess natural variability in water quality. Water quality studies of other surface waters is discussed in Section 5.

2. Methods

The following sampling sites (Figure 4-1) are included in the White River water quality monitoring program:

- Station 27 (above the confluence with Yellow Creek)
- Station 29 (below the confluence with Yellow Creek)

The water quality parameters, analytical methods, and methods of sample preservation which are being used are described in the RBOSC MDP Monitoring Report 1

3. Results and Discussion

Results of the water quality analyses of the White River for the MDP monitoring program (October 1977 through October 1978) are presented in Tables 4-2 and 4-3.

Table 4-4 and 4-5 summarize the water quality data for the White River above and below the confluence with Yellow Creek for the baseline period (October 1974 through September 1976).

Table 4-2. WATER QUALITY DATA FOR THE WHITE RIVER, RBOSC MDP AQUATIC MONITORING STUDIES, OCTOBER 1977 - OCTOBER 1978

Station 27

Parameter[1]	No. of Analyses	Mean	Standard Deviation
Boron (B)	12	<0.5	0.2
Calcium (Ca)	12	65.6	14.6
Chloride (Cl)	12	29.3	9.3
Fluoride (F)	12	0.22	0.05
Magnesium (Mg)	12	23.0	5.6
Nitrate (N)	12	<0.2	0.00
Phosphorus, ortho (P)	12	<0.04	0.06
Phosphorus, total (P)	12	<0.05	0.09
Potassium (K)	12	2.3	0.28
Silica (Si)	12	7.1	1.0
Sodium (Na)	12	47.2	10.25
Solids, total	12	416.1	74.75
Sulfate (S)	12	42.8	13.24

[1] Concentration of dissolved fraction in mg/l unless otherwise noted.

Table 4-3 WATER QUALITY DATA FOR THE WHITE RIVER, RBOSC MDP AQUATIC MONITORING STUDIES, OCTOBER 1977 - OCTOBER 1978

Station 29

Parameter [1]	No. of Analyses	Mean	Standard Deviation
Boron (B)	12	<0.5	0.0
Calcium (Ca)	12	64.8	13.5
Chloride (Cl)	12	33.0	10.6
Fluoride (F)	12	0.23	0.05
Magnesium (Mg)	12	22.0	6.1
Nitrate (N)	12	<0.3	0.25
Phosphorus, ortho (P)	12	<0.02	0.02
Phosphorus, total (P)	12	<0.05	0.08
Potassium (K)	12	2.4	0.31
Silica (Si)	12	7.3	1.06
Sodium (Na)	12	55.9	25.13
Solids, total	12	458.6	95.16
Sulfate (S)	12	43.7	15.06

[1] Concentration of dissolved fraction in mg/l unless otherwise noted.

TABLE 4-4. SUMMARY OF WATER QUALITY DATA FOR STATION 29 ON THE WHITE RIVER, RBOSC BASELINE STUDIES (OCTOBER 1974 THROUGH SEPTEMBER 1976).

Parameter [a]	No. of Analyses	Maximum	Minium	Mean	S.D.
Calcium (Ca)	24	86	35	66.0	1.14
Chloride (Cl)	24	45	8	33.7	1.23
Fluoride (F)	4	0.59	0.27	0.41	1.06
Magnesium (Mg)	24	37	10	27.0	1.28
Nitrate (N)	24	2.00	0.15	0.26	1.84
Phosphorus, Ortho (P)	24	0.06	0.01	0.02	1.57
Phosphorus, Total (P)	24	0.55	0.02	0.05	2.57
Potassium (K)	24	4.3	1.4	2.3	1.33
Silica (Si)	24	18	10	13.0	1.15
Sodium (Na)	24	138	17	66.7	1.27
Solids, Total	24	699	205	471.5	1.22
Sulfate (S)	24	213	42	157.3	1.24

[a] Concentration of dissolved fraction in mg/l unless otherwise noted.

TABLE 4-5. SUMMARY OF WATER QUALITY DATA FOR STATION 27 ON THE WHITE RIVER, RBOSC BASELINE STUDIES (OCTOBER 1974 THROUGH SEPTEMBER 1976).

Parameter [a]	No. of Analyses	Maximum	Minimum	Mean	S.D.
Calcium (Ca)	24	88	36	69.6	1.16
Chloride (Cl)	24	39	8	31.7	1.35
Fluoride (F)	4	0.30	0.27	0.28	1.42
Magnesium (Mg)	24	34	10	25.1	1.30
Nitrate (N)	24	<0.2	<0.2	<0.2	1.80
Phosphorus, Ortho (P)	24	0.04	0.01	0.01	1.74
Phosphorus, Total (P)	24	0.45	0.02	0.06	2.22
Potassium (K)	24	4.0	1.3	2.3	1.37
Silica (Si)	24	18	9	13.2	1.17
Sodium (Na)	24	76	12	57.4	1.54
Solids, Total	24	629	192	481.5	1.38
Sulfate (S)	24	192	39	154.2	1.31

[a]Concentration of dissolved fraction in mg/l unless otherwise noted.

Comparison of the water quality for the MDP and baseline periods for stations 27 and 29 shows very little difference for the two periods. Sulfates and silica levels were somewhat lower during the MDP compared to the baseline period. This may be due to a reduction in the flow or rate of dissolution of a source (groundwater or mineral deposit) which contained high concentrations of these two anions. Fluorides were also lower during the MDP, however, it is difficult to determine if this is a definite trend due to the limited fluoride data (4 observations collected during the baseline period.

A comparison of the water quality data at stations 27 and 29 for the period from October 1977 through October 1978 shows slightly higher concentrations of sodium and total dissolved solids at station 29. This is due to the contribution of dissolved solids from groundwater inflow to Yellow Creek. Nitrate levels were also higher at station 29 during certain times of the year. The elevated levels of nitrate and phosphate during the June 1978 sampling period is probably due to agricultural runoff.

The slight increase in sodium nitrate and TDS levels due to the inflow from Yellow Creek will not affect the overall water quality of the White River.

4.2 BIOTIC COMPONENTS

A. Periphyton

1. Objectives

The objectives of periphyton studies are to monitor species composition, relative abundance, biomass, and diversity of periphyton and to assess the effects of site development on communities of these organisms.

2. Methods

The methods followed for collection of these data were described in the RBOSC MDP Monitoring Report 1.

3. Results and Discussion

Total mean cell densities of the most abundant algal taxa found in the periphyton samples collected during the RBOSC Aquatic Baseline (1974-1976) and MDP (1978) studies are presented in Appendix 4-5.1. Mean dry and organic weights of these periphyton samples are presented in Appendix 4-5.1. Diversity indices are presented in Appendix 4-5.1. Species composition, algal densities, and biomass data for June, July, August, and October 1978 are presented in Appendix 4-3. Total cell densities were generally lower at most stations during 1978 as compared to the baseline period. Diversity indices reflected, to a lesser extent, the lower periphyton densities. Twelve of the Shannon indices in 1978 were slightly to noticably reduced and nine of the 26 Shannon indices were greater than those observed for respective stations during the baseline period. In 1978, the mean organic weights of the periphyton samples at the spring-brook (Tract) stations indicated seven values within the range observed during the baseline period, seven values were higher, and two values lower than those of the baseline studies period Appendix 4-5.1. In 1978, mean organic weights at the White River stations were all lower than those of the baseline studies which also reflected the low total periphyton cell densities observed in 1978.

Total mean cell densities at station 13 were considerably lower in 1978 than for the baseline years. The greatest reduction in cell density from the baseline level occurred in April and August (Table 4-6). Hynes (1970) has noted that total cell densities of periphyton communities are not always similar at the same time each year, especially in streams where unpredictable spring floods cause scouring which result in large fluctuations of algal biomass. The most frequently observed dominant taxa in the periphyton of station 13 during most of 1978 and the baseline studies were Achnanthes minutissima and Navicula pelliculosa. Other taxa which were occasionally dominant during 1978, but were not dominant during baseline studies were Bicoeca lacustus in April and August and Calothrix spp. in July. Taxa which were common or abundant during the baseline studies but absent in 1978 were Meridion circulare in April, Cymbella affinis and Nitzschia capitellata in July and Nitzschia acicularis in October. In 1978, Shannon diversity indices at Station 13 were similar to or greater than those observed during the baseline studies. Organic weights at Station 13 during 1978 were similar to those observed during the baseline studies. In 1978, at Station 14, total periphyton cell densities were always lower as compared to those observed during the baseline period. Samples could not be collected in June and July, 1978 as a result of the scouring from high flows. Periphyton populations were sparse in August 1978 and had not completely recovered in October from the scouring which occurred during June and July.

Shannon diversities at Station 14 in 1978 were similar to those of the baseline period in April and August and noticeably higher than the baseline period in October. In 1978, mean organic weights at Station 14 were within those of the baseline studies in April and greater than those of baseline studies in August and October.

TABLE 4-6. COMPARISON OF MEAN TOTAL CELL DENSITIES OF PERIPHYTON DURING SAMPLING RBOSC MDP STUDIES (1978) AND RBOSP AQUATIC BASELINE STUDIES (1974-1976).

Stations	April			June			July			August			October		
	1975	1976	1978	1975	1976	1978	1975	1976	1978	1975	1976	1978	1974	1975	1978
13	6,334	52,874	403	71	355	357	1,689	26,875	2,329	6,171	2,447	11,313	17,356	26,253	11,288
14	9,929	6,538	4,176	13,412	11,494	-	16,225	2,485	-	10,467	1,822	52	850	723	162
20	2,439	4,287	31,436	5,390	648	1,404	832	1,644	2,328	1,309	4,780	2,335	19,059	9,003	1,257
21	5,645	3,762	19,625	3,405	2,397	1,328	2,259	1,552	3,764	1,047	15,538	2,497	15,087	6,846	645
27	13,790	14,604	6,155	5,742	13,460	-	6,587	10,610	6,622	22,171	7,135	1,717	11,062	17,720	245
29	9,294	7,647	5,740	1,571	13,160	-	10,919	9,984	289	8,071	7,582	2,219	8,732	21,830	554

TABLE 4-7. COMPARISON OF MEAN DRY AND ORGANIC WEIGHTS PERIPHYTON DURING RBOSC MDP STUDIES (1978) AND RBOSC AQUATIC BASELINE STUDIES (1974-1976).

Station	April			June			July			August			October		
	1975	1976	1978	1975	1976	1978	1975	1976	1978	1975	1976	1978	1974	1975	1978
13 DWT	0.3996	0.6250	0.4674	0.3572	0.1260	0.2046	0.2614	0.6711		0.2293	0.2319	0.2273	0.8825	0.5973	1.8568
ORGWT	0.0509	0.1297	0.0348	0.0363	0.0130	0.0294	0.1261	0.0854		0.0516	0.0487	0.0344	0.1477	0.1177	0.1409
14 DWT	2.4702	1.0064	4.0310	0.6395	0.2392		1.3396	0.2855		0.2844	0.6567	2.0905	0.2528	0.1118	1.2780
ORGWT	1.3591	0.0617	0.1470	0.0605	0.0356		0.6283	0.0322		0.0543	0.0415	0.1138	0.0235	0.0231	0.0741
20 DWT	0.6236	0.3026	0.4846	0.2063	0.8422	0.5960	0.3307	0.4376	0.7186	0.2369	3.9732	0.4942	3.4235	0.3546	1.2030
ORGWT	0.0742	0.0423	0.0786	0.0286	0.1136	0.1111	0.0408	0.0816	0.1647	0.0352	0.2427	0.1081	0.1683	0.0463	0.1047
21 DWT	0.7291	0.2610	1.8944	2.0818	2.7975	0.5423	0.3077	1.4562	1.2474	0.4233	0.9344	0.8986	3.6123	0.4738	4.9703
ORGWT	0.1068	0.0377	0.3044	0.4695	0.3247	0.0961	0.0455	0.3855	0.3289	0.0448	0.1178	0.2522	0.1814	0.0539	0.3494
27 DWT	5.2768	2.9986	0.9806	0.8231	37.4821		5.3560	3.4607	0.9152	5.9373	4.8137	0.7292	17.2300	5,6426	0.0808
ORGWT	0.4431	0.3243	0.3243	0.0520	0.0679	0.9772	0.9609	0.2393	0.0801	0.3937	0.3937	0.1864	0.7691	0.4730	0.0074
29 DWT	3.7812	1.9285	0.7512	1.9889	0.9526		0.6992	5.0529	0.0533	3.3818	5.4395	0.5123	5.7952	2.9385	0.1248
ORGWT	0.3468	0.1165	0.0562	0.1625	0.1360		0.6198	0.4579	0.0182	0.3397	0.5694	0.0930	0.4751	0.3747	0.0156

The habitat at Station 14 changed from a mature pond, filled with aquatic macrophytes in 1974 and 1975 to a stream in 1976. In 1977, a pond habitat was created by a new impoundment. The community composition of periphyton in an established pond and a new pond would not be expected to be similar. The species composition of the 1978 and of the 1974-1976 period reflect such differences in the maturity of the habitat. The April and October samples are the only collections in 1978 which are representative of this new pond habitat. In April 1978, Nitzschia capitellata, Navicula arvensis and Navicula pelliculosa were the abundant taxa while in October 1978, Nitzschia frustulum and Nitzschia latens were abundant. Baseline data, from this pond as a mature, weed filled habitat, indicated Achnanthes minutissima to be the prevailing species during both years. Other taxa which were abundant during 1974-1975 and absent in 1978 were Bicoeca lacustris, Cymbella affinis and Nitzschia denticula.

The community composition of periphyton at Stations 20 and 21 on Yellow Creek was similar although total cell densities displayed no definite trend between upstream and downstream stations. In April and July 1978 total cell densities at Stations 20 and 21 were noticeably greater than those of the baseline period. The periphyton community in April 1978 was dominated by Navicula pelliculosa, while the dominant taxon in July was Calothrix spp. a filamentous blue-green. Other commonly observed taxa were Achnanthes minutissima, Nitzschia frustulum and Nitzschia palea. Abundant taxa during April baseline studies at Stations 20 and 21 were Navicula pelliculosa, Achnanthes minutissima, Surirella ovata and Synedra amphicephala while abundant taxa in July were Nitzschia frustulum, Nitzschia fonticola, Achnanthes minutissima and Lyngbya spp.
Total mean cell densities in June, August and October at Stations 20 and 21 were within the range or lower than those observed during baseline studies. A noticeable decrease in the total cell densities at Stations 20 and 21 was observed in October 1978. Species dominance shifted from Achnanthes minutissima in the October collections of the baseline years to Nitzschia frustulum in October 1978. A similar shift in dominance was observed during the baseline studies when Achnanthes minutissima was dominant in the summer of 1975 and Nitzschia frustulum was dominant in the summer of 1976.

In 1978, organic weights at Station 20 were similar to or slightly greater than those of the baseline studies, whereas at Station 21 organic weights were, except in June, at the upper range or greater than those observed during baseline studies. Diversity indices at Stations 20 and 21 were, except in June and October, lower than those observed during the baseline studies.

The total cell densities at Stations 27 and 29 on the White River were lower at both stations on all dates in 1978 (except one) than those of the baseline periods. Periphyton samples were not collected in June 1978 due to flood conditions. The high water and flows (which scour periphyton from substrates) which occurred frequently during spring and summer 1978, probably resulted in the observed low cell densities.

Organic weights at Stations 27 and 29 were lower at both stations on all dates than those observed during the baseline period. Diversity indices at Stations 27 and 29 were, when compared to those of the baseline studies, lower in April and August and similar in July and October.

Dominant taxa at both stations in April 1978 were Gomphonema olivaceum and Navicula pelliculosa whereas the abundant taxa during the baseline studies were Navicula viridula, Navicula cryptocephala, Nitzschia dissipata and Epithemia sorex.

In July and August 1978, filamentous blue-green algae such as Calothrix and Lyngbya were dominant, whereas during baseline studies Calothrix and Lyngbya were codominant with several diatoms, such as Navicula spp. Nitzschia spp. and Epithemia sorex. Epithemia, Navicula and Nitzschia were also abundant in October of the baseline studies while in October 1978 total cell densities were sparse and the dominant taxa were Gomphonema spp. and Achnanthes minutissima.

During 1978, scouring of underwater substrates due to frequent high flows (resulting from discharge from dewatering operations) caused reduced total periphyton cell densities, mean organic weights, and diversity indices at many of the stations as compared to those observed during the baseline period.

In several instances at the same sampling station, high organic weights and low cell densities were observed. In these instances, the high organic weights can be attributed to the occurrence of large quantities of organic detritus and invertebrates in the sample.

The species composition of the periphyton community at all stations during 1978 were frequently similar to those observed during the baseline studies. Cell densities occasionally fluctuated qreatly and the seasonal peak of many taxa occurred at different periods as compared to those of the baseline period.

At all six sampling stations, Achnanthes minutissima, an indicator of clean water and high oxygen concentrations, (Lowe 1974; Schoeman 1973), was common or abundant on at least one sampling date during both 1978 and the baseline period.

Taxa such as Navicula pelliculosa, Nitzschia frustulum, Gomphonema olivaceum, Epithemia sorex and Calothrix, which were abundant in 1978 as well as the baseline studies, are indicative of high pH and alkalinities (Lowe 1974; Schoeman 1973). In 1978, at least 14 of the 26 Shannon indices were greater or similar to those observed during the baseline studies. Thus, the periphyton community, despite scouring from high flows which frequently caused low total cell densities, organic weights, and occasionally diversity indices, continued to be a fairly diverse community which is indicative of oxygenated, highly alkaline waters at all stations.

Since the same dominant taxa were present at the respective stations in 1978 as compared to the baseline studies, and a species dominance shift toward pollution tolerant taxa has not occurred, no major impact on the species composition of the periphyton communities can be detected due to MDP development.

B. Benthos

1. Objectives

The objectives of the benthos (macroinvertebrate) studies are to assess the effects of site development on benthos communities. Benthos studies are included in the RBOSC MDP monitoring program because benthic macroinvertebrates constitute the major component of the secondary trophic level in aquatic ecosystems on and near Tract C-a, and because of their limited mobility and consequent susceptibility to physical and chemical changes.

2. Methods

The methods used in collecting these data were described in RBOSC MDP Monitoring Report 1. (1977).

3. Results and Discussion

The results of the benthos monitoring program in 1978 are given in Appendix 4-4. Data are compared with the 1974-1976 baseline program in Appendix 4-5.2. Species diversity for 1978 is presented in Appendix 4-5.2. These indices are also compared with the 1974-1976 baseline period. The taxa listed in this Appendix were the most abundant taxa at each station through the baseline and monitoring programs.

At Station 13, the density of macroinvertebrates was lower than at other stations in the study area. In October, 1978, the family Naididae, a group of aquatic worms, was most abundant with over 1600 organisms/M^2. Chironomidae larvae were also a numerically important component of the benthos at this station. The number of species found at this station was low as reflected by the continually low species diversity.

Benthos samples from Station 14 were more diverse than those of Station 13 during 1978. The annelid family Tubificidae and the dipteran family Chironomidae were abundant at this station, with another dipteran family Simuliidae also being numerically important.

At Station 20, Chironomidae, Simuliidae, and Ceratopogonidae were collected in fairly large numbers on most of the sampling dates. The number of taxa collected and the diversity at Station 20 was relatively high. Station 21 contained a benthic fauna consisting of Chironomidae larvae, Simuliidae, and Ceratopogonidae as the most important and dominant organisms.

Numerous genera of the Class Insecta, such as the mayflies Tricorythodes and Ephemerella , were present at Station 27. This station had a well-balanced community; representatives of most of the macroinvertebrates groups of the region were present. Diversity was high at Station 27 as were the number of species. The Class Insecta formed a significant proportion of the benthic community at Station 29. Rhithrogena, Baetidae, Hydropsychidae, and Hydropsyche were commonly found at Station 29 during 1978 as at Station 27. The benthic community at station 29 appeared to be quite diverse with representatives of many different macroinvertebrates groups being present.

A comparison of benthic populations during the baseline program with those of the MDP monitoring program was conducted to determine if changes occurred in the density and diversity of the benthic community. Appendix 4-5.2 presents the density of major taxa and diversity of the benthic community at Station 13, 14, 20, 21, 27, and 29 during the months of April, June, July, August, and October of 1974, 1976, and 1978.

Station 13 in 1978, had a very few species. In previous years (1974 & 1975) this station generally had a higher number of species and a well-balanced benthic community based upon the Shannon Index (Appendix 4-5.2). The benthic

community at this station has undergone a radical change in the numbers of species and in the kinds of taxa collected. During 1974 and 1975, many Baetidae, Plecoptera, Naididae and Chironomidae larvae were collected. During 1978, however, all taxa were reduced in number and many were absent. At station 14, the habitat has undergone considerable change throughout the years making year-to-year comparisons difficult. Originally, this station was a pond habitat. In 1976 high waters completely destroyed the pond and drastically altered the benthic habitat. Callibaetis, a mayfly, was one of the taxa which disappeared as a result of this habitat destruction. The station, at present, is again a pond-like habitat, but without the abundant macrophytes which formerly existed. Based on the faunal composition, the pond appears to be a depositional area. The number of Tubificidae collected at Station 14 have tended to increase over the study period (1974-1978). Conversely, Baetidae (Callibaetis), showed a downward population trend as did Chironomidae larvae until 1978.

The invertebrate population collected at Station 20 in the period 1974-1978 was quite stable as compared with Station 13 and 14. The number of organisms, especially the Tubificidae and Chironomidae, fluctuated, but showed no definite trends over the period. The benthic community at Station 21 contained a high proportion of taxa within the Phylum Annelida and Order Diptera. An increase in numbers of Chironomidae and Simuliidae occurred in some months, but no long-term trends were apparent.

Station 27 consistently had the most diverse benthic community of all stations sampled in 1974-1978. Large numbers of Insecta were present, especially mayflies such as Ephemerella, Tricorythodes, Rhithrogena, and Baetidae. Hydropsyche and Chironomidae larvae were also present in significant numbers. In June of 1975 and 1978, samples could not be obtained because of high water. In july of 1975, very few organisms were found as compared to later years; a similar trend occurred at Station 29. The reasons for this low diversity was unknown.

The benthic macroinvertebrates sampled during the study period at Station 29 were typical of swift flowing waters. Rhithrogena, Traverella, Baetidae, and Plecoptera were collected at Station 29. The benthic population at this station has undergone little net change over the study years from 1974 to 1978, and has remained a stable and well balanced benthic community.

As noted in previous RBOSC investigations, Station 13 has had a substrate of gravel, sand and silt. The physical composition of the sediments resembled that at the headwater stations, however, the number of species, richness (which relates the number of species to the number of individuals) and diversity indices were lower. Periods of very low flow at Station 13 were believed to be one of the major reasons for the differences. Recently, however, the character of Station 13 has been altered by extremely high flows in spring and early summer of 1978, due to the discharge of water from pump testing operations. This has resulted in a scouring of the streambed which has reduced the number and kinds of species present, and,in some cases, eliminated certain taxa.

Previously Station 14 was a pond habitat. This pond received flow from a seepage area and had extensive growths of the macrophyte, Zannichelia palustris. The benthos population in the pond included Callibaetis, Corixidae, Dytiscidae,certain Chironomidae such as Micropseitra, and Ceratopogonidae, and Anthomyiidae. Aquatic worms such as Naididae and Enchytraeidae were common. The pond also contained a few tubificids. However, this pond habitat was washed out and replaced by a lotic habitat for a period of time. Presently, a newly formed pond exists at Station 14. This pond, however, does not contain the macrophytic growth that was present during the earlier years of sampling. The population of Callibaetis, which inhabited the macrophytic growth in huge numbers, were beginning to recover in 1978, as were other Baetidae. The tubificids, on the other hand, increased in number over the previous years, suggesting a depositional area had formed.

The Yellow Creek Station 20 had been characterized in former reports as having very high dissolved solids concentrations. Densities of certain taxa, historically, have been extremely high at the Yellow Creek Station. However, species diversity indices for these stations have been quite low due to the dominance of a few taxa. High salt content is believed to be one of the factors which limit the diversity in this creek. The benthic community at Station 20 appeared to be quite stable and has changed little over the past years.

The benthic population at Station 21 was similar to that at Station 20, being a relatively stable community.

The White River Stations 27 and 29 continued to be the most diverse benthic community in the study area. The river is characterized by a rubble bottom with many interstitial areas available to benthic organisims for colonization. Densities of macroinvertebrates are lower in the White River than in the Yellow Creek drainage. Due to the large numbers of genera of mayflies, caddisflies, and stoneflies, the diversity is high. The benthos at Station 27 and 29 remained stable and well-balanced throughout the entire study.

The macroinvertebrate composition at Station 13 has noticeably changed from the baseline conditions of 1974-1975. In 1976, Station 13 supported very few Ephemeroptera, Plecoptera, Naididae or Chironomidae larvae. The decrease in taxa and decrease in numbers of organisms (density) at station 13 is believed to be related to discharge from pumping of dewatering wells. High flows with increased velocities in spring and early summer due to discharge of water from dewatering operations has caused the sandy substrate to scour the bed and destroy a substantial portion of the fauna. The faunal community should return to normal once the pumping has ceased. Because the habitat at station 14 has not remained stable, i.e., it has changed from a semi-lentic habitat to a lotic one and then reverted to a semi-lentic habitat again, it is difficult to come to any strong conclusions concerning this station. When the pond habitat was destroyed the pond forms such as Callibaetis were no longer present. In 1978 some of the pond forms have begun to return to this station as it once again

became pond-like. The increasing numbers of tubificids in 1978 suggests that station 14 is presently in a depositional phase.

The Yellow Creek and White River Stations were comparable in both the baseline and Monitoring Programs. Although there were some substantial density fluctuations for particular taxa on the White River, this is believed to be due to natural variability within the aquatic system.

4.3 DATA ANALYSIS

A. Statistical Analysis of RBOSC Periphyton Density

1. Summary of the Statistical Analysis

Total periphyton density and the density of selected periphyton groups were analysed using an analysis of variance in a completely randomized design. The periphyton groups selected for detailed analysis were Chlorophyta, Chrysophyta, and Cyanophyta. Mean differences in density between phases of development, among sampling dates within phases, and among sampling sites were tested for statistical significance. The interaction between sampling sites and development phase was included in the analysis. Mean differences in periphyton density among sampling dates within each development phase sampling site combination were also compared.

2. Explanation of the Factors Used in the Analysis

Based on the phase of development, the sampling period was divided into two parts. Phase I is is the baseline period (1974-1976). Phase 2 indicates the developmental monitoring period (1978). The sampling sites included in the analysis are sites 13, 14, 20, 21, 27, and 29. The sampling dates referred to are November 1974, April 1975, June 1975, July 1975, September 1975, October 1975, April 1976, June 1976, July 1976, September 1976, April 1978, June 1978, July 1978, August 1978, and October 1978.

3. Transformation of the Data

In order to increase the likelihood of meeting the assumptions of the analysis of variance, the data were transformed prior to statistical analysis. Using a procedure outlined by Box and Cox (1964), the transformation which minimized the estimate of the system's inherent variation was selected for each dependent variable (i.e., total density, density of each periphyton group). Based on the Box and Cox procedure, it was decided to transform the data with the reciprocal transformation.

4. The Results of the Analysis

The results of the analysis are summarized in Table 4-8. Complete analysis of variance tables for the total periphyton density and each group density are listed in Table 4-9. All group means and the mean total density of periphyton were significantly different between phases.

There was a significant difference in mean total density among dates within phases. Mean densities of Cyanophyta, Chlorophyta, and Chrysophyta did not differ significantly among dates within phases.

Mean total periphyton density and the mean density of Chlorophyta differed significantly among sites. There was no statistically significant difference among sites in the mean density of Cyanophyta and Chrysophyta.

The site by phase interaction was significant for total periphyton density and the density of Cyanophyta. This indicates that the mean difference in total density and density of Cyanophyta among sites was not consistent across phases. The site by phase interaction was not significant for Chlorophyta and Chrysophyta density. The lack of statistical significance for the phase site interaction suggests that the mean differences in Chlorophyta and Chrysophyta densities were consistent across developmental phases.

Only total periphyton densities showed a significant difference among dates within each site phase combination. Densities of Cyanophyta, Chlorophyta, and Chrysophyta did not differ significantly among dates within each site phase combination.

B. RBOSC Periphyton Biomass Data Analysis

1. Summary of the Statistical Analysis

The RBOSC periphyton biomass data was analysed using an analysis of variance in a completely randomized design. Mean differences in periphyton dry weight and organic between phases of development, among sampling dates within phases, and among sampling sites were tested for statistical significance. The interaction between sampling sites and development phase was included in the

TABLE 4-8. RESULTS OF ANALYSIS OF VARIANCE FOR PERIPHYTON

Total Periphyton

Source	df	Mean Squares	F	Prob
Phase	1	6.182097	16.486	0.0014
Date (phase)	13	0.374994	2.076	0.0164
Site	5	1.419051	3.508	0.0076
Site x Phase	5	1.311974	3.243	0.0117
Date (site x phase)	60	0.404564	2.239	0.0000
Error	230	0.180649		

Cyanophyta

Phase	1	3.156646	9.516	0.0087
Date (phase)	13	0.331731	0.479	0.9349
Site	5	1.572419	2.184	0.0677
Site x phase	5	1.709243	2.374	0.0495
Date (site x phase)	60	0.719842	1.040	0.4093
Error	230	0.692487		

Chlorophyta

Phase	1	0.314309	4.796	0.0474
Date (phase)	13	0.065530	0.612	0.8432
Site	5	0.272254	2.568	0.0359
Site x Phase	5	0.223988	2.113	0.0761
Date (site x phase)	60	0.106013	0.990	0.5038
Error	230	0.107099		

Chrysophyta

Phase	1	17.146458	7.832	0.0151
Date (phase)	13	2.189302	1.489	0.1222
Site	5	2.778728	2.240	0.0618
Phase x Site	5	2.102056	1.695	0.1498
Date (Phase x site)	60	1.240498	0.844	0.7801
Error	230	1.470043		

TABLE 4-9. SUMMARY OF RESULTS OF ANALYSIS OF VARIANCE.

	Source	df	Total	Cyanophyta	Chlorophyta	Chrysophyta	Test
1.	Phase	1	**	**	*	*	1/2
2.	Date (phase)	13	*	NS	NS	NS	2/6
3.	Site	5	**	NS	*	NS	3/5
4.	Site x Phase	5	**	*	NS	NS	4/6
5.	Date (site x phase)	60	**	NS	NS	NS	5/6
	Error	230					

* = $p < .05$

** - $p < .01$

NS - no statistical significance

NOTE: Complete analysis of variance tables for the total periphyton density and each group density are listed on the following tables.

analysis. That is, the mean differences in biomass at each site were tested for consistency across phases. Mean differences in biomass among sampling dates within each development phase-sampling site combination were also compared.

2. Explanation of the Factors Used in the Analysis

Based on the phase of development, the sampling period was divided into two parts. Phase 1 is the period before construction was started (1974-1976). Phase 2 indicates the period during construction (1978). The sampling sites included in the analysis are sites 13, 14, 20, 21, 27, and 29. The sampling dates referred to in the analysis are November 1974, April 1975, June 1975, July 1975, September 1975, October 1975, April 1976, June 1976, July 1976, September 1976, April 1978, June 1978, July 1978, August 1978, and October 1978.

3. Transformation of the Data

In order to increase the likelihood of meeting the assumptions of the analysis of variance, some of the data were transformed prior to the analysis. Using a procedure outlined by Box and Cox (1964), the transformation which minimized the estimate of the system's inherent variation was selected for each dependent variable (i.e., dry weight, and organic weight). Using this criteria, it was decided to transform the dry weight criteria, it was decided to transform the dry weight data with the reciprocal transformation. No transformation of the organic weights was necessary.

4. Results of the Analysis

The results of the analysis are summarized in Table 4-10. Mean differences between phases in the organic weight of periphyton were statistically significant ($p = .0403$). There was, however, no significant difference between phases in the dry weight of the periphyton.

TABLE 4-10. ANALYSIS OF VARIANCE FOR PERIPHYTON BIOMASS

			Dry Weight			Organic Weight		
	Source	df	Mean Square	F-ratio	Test	Mean Square	F-ratio	Test
1.	Phase	1	49.08	3.49	1/2	.667	5.18*	1/2
2.	Date (Phase)	13	14.06	5.73**	2/6	.129	1.22	2/6
3.	Site	5	41.00	2.58*	3/5	.152	1.19	3/5
4.	Site x Phase	5	97.22	6.11**	4/5	.280	2.19	4/5
5.	Date (Site x Phase)	60	15.92	6.49**	5/6	.127	1.21	5/6
6.	Error	141	2.46			.106		

*indicates significance at the .05 probability level
**indicates significance at the .01 probability level

There was a highly significant difference ($p = .001$) in mean periphyton dry weight among sampling dates within each phase. The mean organic weight of the periphyton did not differ significantly among sampling dates within each phase.

Mean periphyton dry weight varied significantly ($p = .0355$) among the sampling sites, while mean periphyton organic weight showed no statistically significant difference among sites. The interaction between phase and site was significant ($p = .0001$) for periphyton dry weight indicating that mean dry weight did not vary consistently over development phase. The phase-site interaction was non-significant for periphyton organic weight. The lack of statistical significance for phase-site interaction suggests the mean differences in periphyton dry weight among sites were consistent across development phases.

Mean periphyton dry weight varied significantly ($p = .0001$) among sampling dates within each sampling site and phase combination. Mean periphyton organic weight showed no statistically significant difference among sampling dates within each site-phase combination.

C. Periphyton Similarity Index Analyses

In order to provide a more quantifiable comparison of the periphyton communities sampled in 1978 with those collected in baseline years (1975, 1976), the similarity index $C = \frac{2w}{a + b}$ was employed (Bray and Curtis, 1957). This index has been used in phytosociological studies to provide a means of numerically comparing the similarities of plant associations (ibid). The components of this formula are w, the sum of the lower values for each "measure"; a, the sume of all measures for one of the communities being compared; and b, the sum of all measures for the other community. The resulting index may vary from zero for two communities with no measurements in common, to 1.00 (or 100%) for two quantitatively indentical communities. The "measure" utilized in this case is abundance of each species in the periphyton community.

The similarity indices (c) presented in Appendix 4-5.3 include comparisons of the mean composition and relative abundance of each sampling date/station with every other sampling date/station. Replicate samples were combined and averaged in order to reduce the print-out volume and to enhance the accuracy of the comparisons.

For any station, similarity indices (c) for equivalent months during baseline years were sometimes low (0.16-0.32) whereas when two adjacent months were compared the c values were frequently high (0.53-0.82). This indicates that communities in these habitats have populations that do not always peak in the same month each year. Population peaks may occur a month or two earlier or later depending on prevailing conditions. Similarity among adjacent months also indicates that an established community tends to prevail for several months. The most important variable for periphyton communities in the vicinity of RBOSC tract is probably flow. High flows due to rains and snow melt result in scouring of underwater substrates. After high flows subside recolonization and growth of periphyton populations to normal densities may require as much as four to six weeks.

In order to compare the similarity of communities between baseline and MDP monitoring years, c values for comparable months of the years being compared were averaged (Table 4-11). Although sampling dates were not entirely equivalent for all years compared, at least one sampling date from each season was deemed comparable.

Mean c values comparing 1975 and 1976 baseline data were lowest at Station 20, moderate at Stations 13, 14 and 21 and highest at Stations 27 and 29. These mean values appear low compared to other periphyton studies (Owen 1973), but may be typical of stream habitats subject to extremes in flow. These data reflect the relative stability of the communities studied; the upstream environments (Stations 13, 14) tended to be more stable than those of Yellow Creek proper (Stations 20, 21) while the large river habitat of White River (Stations 27, 29) tended to the most stable and exhibit the greatest similarity among sampling dates and years.

Similarity indices comparing each year of baseline data with the 1978 MDP monitoring data indicated comparable values at Stations 13 and 20 and lower values at Stations 14, 21, 27 and 29 (Table 4-11).

The noticeable reduction in similarity of 1978 data for Station 29 as compared to baseline years was largely due to the increased abundance of Navicula pelliculosa in April and Calothrix sp. in June, July and August, 1978. Navicula pelliculosa was frequently abundant at the headwater stations during the baseline studies and its dominance at Station 21 in 1978 is not indicative of any environmental impact. Calothrix was abundant in may of the baseline and MDP monitoring collections from the White River, its dominance at Stations 20 and 21 on Yellow Creek is not considered unusual.

The lower similarities of MDP monitoring data and baseline data for Stations 27 and 29 as compared to similarities of baseline years probably reflect the reduction of overall cell densities at these stations in 1978. This was attributed to scouring from several spring and summer

TABLE 4-11. SIMILARITY INDICES (c) COMPARING PERIPHYTON OF BASELINE YEARS, AND BASELINE AND MDP MONITORING YEARS (Based on mean of c of all equivalent months)

Station	1975 + 1976	1975 + 1978	1976 + 1978
13	0.32	0.33	0.31
14	0.35	0.19	0.20
20	0.24	0.22	0.29
21	0.32	0.23	0.26
27	0.41	0.24	0.28
29	0.41	0.22	0.26

floods. In addition, the reduction in similarity was common to both stations, indicating that Yellow Creek influence was not the casual factor.

In conclusion, the indices demonstrated that the periphyton communities of the tract area are highly variable and often bear little similarity between years when undisturbed. Similarity indices did not indicate any changes of periphyton communities from the baseline period to the MDP monitoring period, other than those attributable to habitat naturally occurring alterations.

D. Benthic Density Data

1. Summary of the Statistical Analysis

Total benthic density and the density of selected benthic groups were analyzed using an analysis of variance in a completely randomized design. The benthic groups selected for detailed analysis were Nematoda, Tubificidae, Insecta, Ephemeroptera, Plecoptera, Trichoptera, Diptera, Ceratopogonidae, Chironomnidae and Simuliidae. Mean differences in density between phases of development, among sampling dates within phases and among sampling sites were tested for statistical significance. The intereaction between sampling sites and development phase was included in the analysis. Mean differences in density among sampling dates within each development phase-sampling site combination were also compared.

2. Explanation of the Factors used in the Analysis

Based on the phase of development, the sampling period was divided into two parts. Phase I is the baseline period (1974-1976). Phase 2 indicates the developmental monitoring period (1978). The sampling sites included in the analysis are sites 13, 14, 20, 21, 27 and 29. The sampling dates referred to are October 1974, April 1975, June 1975, July 1975, September 1975, October 1975, April 1976, June 1976, July 1976, September 1976, April 1978, June 1978, July 1978, August 1978 and October 1978.

3. Transformation of the Data

In order to increase the liklehood of meeting the assumptions of the analysis of variance, the data were transformed prior to statistical analysis. Using a procedure outlined by Box and Cox (1964), the transformation which minimized the estimate of the system's inherent variation was selected for each dependent variable (i.e., total density, density of each benthic group). Based on the Box-Cox procedure, it was decided to transform the data with the reciprocal transformation.

4. The Results of the Analysis

The results of the analysis are summarized in Table 4-11 and 4-12. There were no statistically significant difference between phases in mean total density or in any of the mean group densities. There was a significant difference among sampling dates within each phase in mean total density and in the mean densities of Insecta, Ephemeroptera, Plecoptera, Trichoptera, Diptera, Chironomidae and Simuliidae. Nematoda, Tubificidae and Ceratopogonidae showed no significant difference in mean density among sampling dates within each phase.

There was no significant difference among sites in mean total density or in any group mean densities. The site by phase interaction was non-significant for total density and for all group densities. The lack of statistical significance for the phase-site interaction suggest the mean difference in benthic density among sites was consistent across development phases.

Mean total density and all mean group densities, except mean densities of Nematoda and Ceratopogonidae, were significantly different among sampling dates within each sampling site-developement phase combination.

TABLE 4-12. ANALYSIS OF VARIANCE OF THE BENTHIC DENSITY DATA

ANALYSIS OF VARIANCE-TOTAL DENSITY

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.004226	0.009	0.9259	NS
Date (Phase)	13	0.470119	6.841	0.0000	.01
Site	5	0.139960	0.542	0.6687	NS
Site x Phase	5	0.235316	1.079	0.3812	NS
Date (Site x Phase)	60	0.218089	3.174	0.0000	.01
Error	165	0.068720			

ANALYSIS OF VARIANCE-NEMATODA

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.002270	0.943	0.3753	NS
Date (Phase)	13	0.002693	0.670	0.7907	NS
Site	5	0.003348	0.622	0.6835	NS
Site x Phase	5	0.005221	0.370	0.4435	NS
Date (Site x Phase)	60	0.005383	1.338	0.0770	NS
Error	165	0.004023			

ANALYSIS OF VARIANCE-EPHEMEROPTERA

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.017869	0.079	0.7836	NS
Date (Phase)	13	0.227327	1.945	0.0285	.05
Site	5	0.568541	1.995	0.0922	NS
Site x Phase	5	0.128417	0.451	0.8111	NS
Date (Site x Phase)	60	2.84927	2.438	0.0000	.01
Error	165	0.116800			

ANALYSIS OF VARIANCE-TUBIFICIDA

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.001249	0.103	0.7537	NS
Date (Phase)	13	0.012163	1.238	0.2566	NS
Site	5	0.023923	1.034	0.4060	NS
Site x Phase	5	0.019729	0.853	0.5181	NS
Date (Site x Phase)	60	0.023133	2.355	0.0000	.01
Error	165	0.009823			

TABLE 4-12. (Cont.) ANALYSIS OF VARIANCE OF THE BENTHIC DENSITY DATA

ANALYSIS OF VARIANCE-INSECTA

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.233651	0.413	0.5318	NS
Date (Phase)	13	0.566358	15.098	0.0000	.01
Site	5	0.766153	2.356	0.0510	NS
Site x Phase	5	0.740165	2.276	0.0582	NS
Date (Site x Phase)	60	0.325183	8.669	0.0000	.01
Error	165	0.037513			

ANALYSIS OF VARIANCE-CHIRONOMIDAE

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	7.982319	0.193	0.6673	NS
Date (Phase)	13	41.265520	4.863	0.0000	.01
Site	5	9.211000	0.566	0.7255	NS
Site x Phase	5	4.572384	0.281	0.9217	NS
Date (Site x Phase)	60	16.268890	1.917	0.0007	.01
Error	165	8.486178			

ANALYSIS OF VARIANCE-PLECOPTERA

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.029330	0.604	0.4511	NS
Date (Phase)	13	0.048580	6.710	0.0000	.01
Site	5	0.064023	2.092	0.0788	NS
Site x Phase	5	0.004239	0.139	0.9826	NS
Date (Site x Phase)	60	0.030604	4.227	0.0000	.01
Error	165	0.007240			

ANALYSIS OF VARIANCE-DIPTERA

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	5.965149	0.166	0.6904	NS
Date (Phase)	13	35.954578	5.090	0.0000	.01
Site	5	9.325711	0.581	0.7143	NS
Site x Phase	5	5.064140	0.316	0.9017	NS
Date (Site x Phase)	60	16.048613	2.272	0.0000	.01
Error	165	7.063618			

TABLE 4-12. (Cont.) ANALYSIS OF VARIANCE OF THE BENTHIC DENSITY DATA

ANALYSIS OF VARIANCE-TRICHOPTERA

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.339042	0.290	0.5992	NS
Date (Phase)	13	1.168202	5.964	0.0000	.01
Site	5	0.326901	0.615	0.6887	NS
Phase x Site	5	0.153647	0.289	0.9172	NS
Date (Site x Phase)	60	0.531500	2.713	0.0000	.01
Error	165	0.195887			

ANALYSIS OF VARIANCE-SIMULIIDAE

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.378722	0.278	0.6070	NS
Date (Phase)	13	1.362891	2.656	0.0021	.01
Site	5	0.341396	0.467	0.7989	NS
Site x Phase	5	0.201683	0.276	0.9244	NS
Date (Site x Phase)	60	0.730263	1.423	0.0421	.05
Error	165	0.513138			

ANALYSIS OF VARIANCE-CERATOPOGONIDAE

Source	D.F.	Mean Squares	F	Prob	Signif[a]
Phase	1	0.017153	1.837	0.1984	NS
Date (Phase)	13	0.009337	1.559	0.1017	NS
Site	5	0.006901	0.871	0.5061	NS
Site x Phase	5	0.013430	1.695	0.1498	NS
Date (Site x Phase)	60	0.007925	1.324	0.0850	NS
Error	165	0.005987			

[a]NS - non-signficant
.01 - significant at the .01 probability level
.05 - significant at the .05 probability level

Bray, J. R. and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27:325-349.

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Lowe, R. L. 1974. Environmental Requirements and Pollution Tolerance of Freshwater Diatoms. EPA-670/4-74-005. USEPA, Cincinnati, Ohio. 334 p.

Owen, B. B. Jr. 1973. The effects of increased temperatures on periphyton communities of artificial stream channels. Ph.D. Thesis. Univ. of Alberta, Canada. 242 p.

RBOSC. 1978. RBOSC MDP Monitoring Report 1. Gulf-Standard, Denver, Co.

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SECTION 5

HYDROLOGY STUDIES

Among the activities connected with oil shale development on Tract C-a, those with the greatest potential effect upon surface and groundwater quantity and quality are upper aquifer dewatering, injection of upper aquifer water back into the upper aquifer, discharge of upper aquifer water into surface streams, earth-moving activities associated with the support facilities of the mine, road construction, and other miscellaneous discharges. Rio Blanco Oil Shale Company has monitored these potential impacts through two basic programs, (1) the environmental hydrologic monitoring program, and (2) the operational hydrologic monitoring program.

In general, the environmental hydrologic program is conducted at a distance from the mining activities. During the baseline and subsequent monitoring periods, surface water data have been collected from springs and seeps and surface water gaging stations. Groundwater data have been collected from alluvial monitoring holes and from upper aquifer and lower aquifer wells. Figure 5-1 shows the location of these stations. Additional data were collected during the Modular Development Phase (MDP) Pump Test at three surface water gaging stations, seven alluvial monitoring locations, and fourteen sediment and erosion stations.

The operational hydrologic monitoring program collects the bulk of its data on-tract. These data include the quantification of mine water discharges, reinjection and dewatering.

This report covers the data collected and received during the period of June 1978 through November 1978. It presents the first detailed statistical analysis of data since the Final Environmental Baseline Report, and, in general, the analysis includes data collected from December 1977 through November 1978.

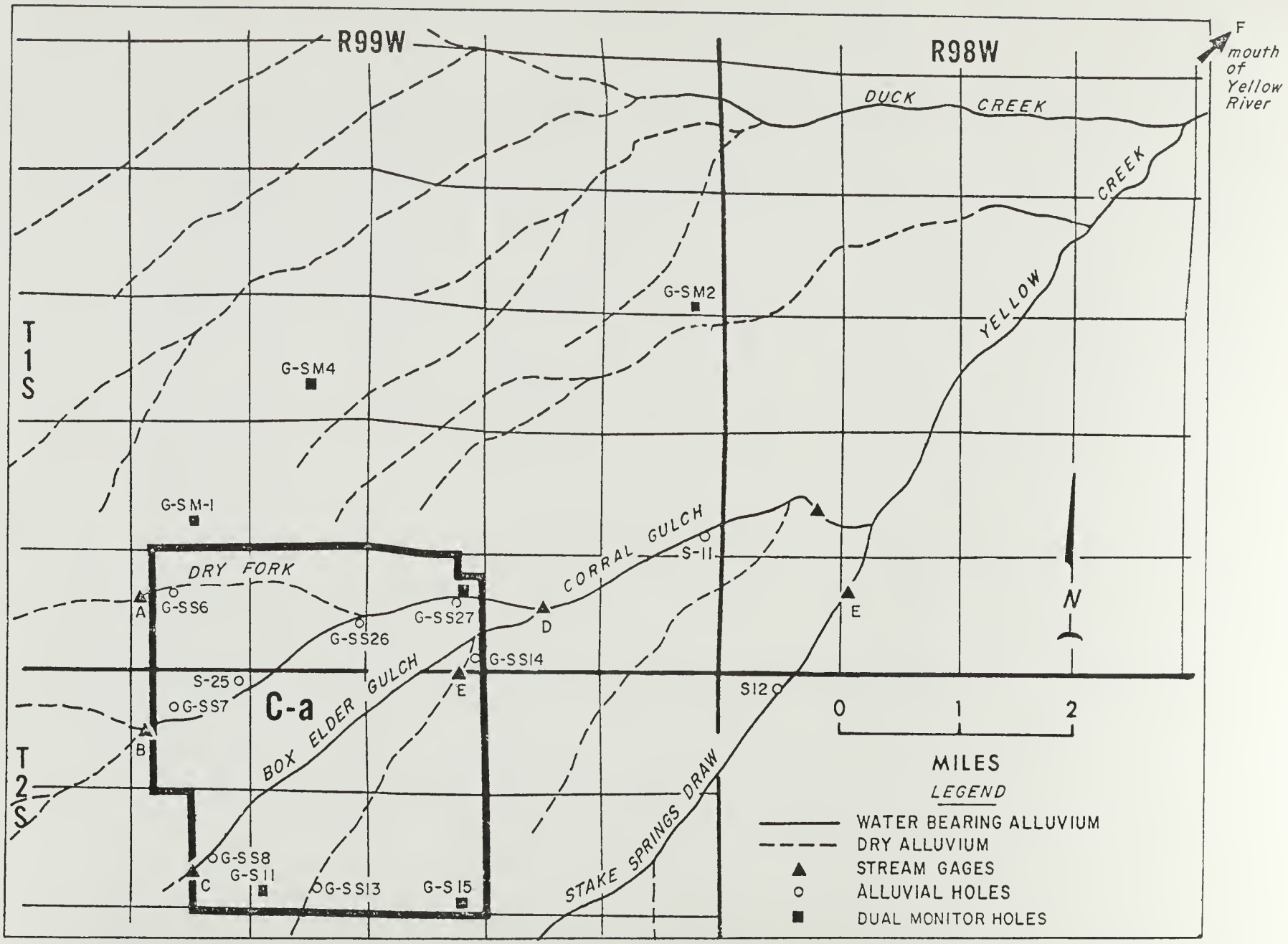

Figure 5-1. Locations of Monitoring Stations for Hydrology Studies During the MDP.

5.1 SURFACE WATER

A. Streams

1. Objectives - The objective of the surface water monitoring is to determine if surface water quantity and quality are affected by the Tract C-a MIS mining activities and the construction of associated facilities.

2. Methods - The methods of collection of hydrology data were described in RBOSC MDP Monitoring Report 1 and are not repeated herein. The number of stream gaging stations, however, was reduced from seven to six, with the closure of operations at Stake Springs Draw near its confluence with Corral Gulch. Table 5-1 identifies the USGS numbers and tributary areas of the remaining stations.

TABLE 5-1. GAGING STATION IDENTIFICATION NUMBERS AND DRAINAGE AREAS

USGS I.D. No.	Location	Drainage Area Square Miles
09306237	Dry Fork near west line Tract C-a	2.91
09306235	Corral Gulch near west line Tract C-a	8.44
09306240	Box Elder Gulch near west line Tract C-a	10.29
09306242	Corral Gulch east of Tract C-a	29.59
09306230	Stake Springs Draw near confluence with Corral Gulch	31.61
09306255	Yellow Creek near White River, Colorado	262.00
09306241	"Rinky Dink" Gulch near east line Tract C-a	2.25.

3. Results and Discussions

a. Physical Parameters - Table 5-2 is a surface gaging station flow and sampling summary for the water years 1976 through 1978. In the base-line study, gages at each of the stations recorded some flow. During the period 1977 through 1978, Rinky-Dink Gulch was the only station at which no flow was recorded. The station at Corral Gulch east of Tract C-a recorded continuous flow throughout the study period. Yellow Creek station reported continuous flow except during September 1978. The flow at the Corral Gulch

TABLE 5-2 SURFACE GAGING STATION FLOW AND SAMPLING SUMMARY TRACT C-a

Location	1976				1977												1978											
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	
Corral Gulch near West Line Tract C-a	X S	X S	I	I		I	I S	I S		I	I	I	I	I					I S	I	I S	X S	I	X	X S	X		
Dry Fork near West Line Tract C-a											I	I	I	S														
Box Elder Gulch near West Line Tract C-a											I	I S	I						I S	X S	X	I S						
Corral Gulch East of Tract C-a	X S	X S	X	X	X S	X	X	X S	X	X	X	X S	X	X S	X	X S	X S	X	X S	X S	X	X S	X	X	X S	X S		
Yellow Creek near White River, Colo.	X S	X S	X S	X	X	X	X	X S	X	X	X	X S	X	X S	X	X S	X	X	X S	X	X	X S	X	X	I S	X S		

X - Flow recorded during entire month

I - Intermittent flow recorded during month

S - Sample collected during month

Station at the west line of Tract C-a was more sporadic than in the earlier years of study. Dry Fork continued to be predominantly dry, while Box Elder showed intermittent flow. The table also shows the months during which water quality samples were taken.

The natural flows for water years 1977 and 1978 bore a striking resemblance to those of 1976 and 1975, respectively, at all gaging stations. During 1977, monthly mean flows at the six stations showed approximately the same graphic configurations as those of the 1976 baseline study, although the total yearly flows at these stations were slightly lower than the preceding year (Figures 5-2 and 5-2a). Snowmelt at Box Elder Gulch occurred during April and May 1978. In September 1978, the largest single runoff event recorded to date occurred at the Yellow Creek station. In general, however, the patterns of flow recorded at each of the gages prior to the discharge of water from the dewatering program repeated those of the water year 1975.

Table 5-3 summarizes the annual runoff in acre-feet from 1975 to 1978. Water year 1977 showed the effects of the drought at all the stations except Dry Fork, which did not suffer a reduction in runoff until 1978. The 1978 increase in runoff at Corral Gulch West and Box Elder Gulch stations represented a return to more normal flows from drought conditions. Downstream of the dewatering activities, at the Corral Gulch East gaging station, however, the annual runoff increased from a maximum of 626.2 acre-feet during the baseline period to 1,399 acre-feet.

Figure 5-3 shows the discharge to Corral Gulch from two different data sources, the NPDES reports and the Subsurface Disposal Permit report. Reinjection and total dewatering quantities which appear on this figure are from the Subsurface Disposal Report.

As can be noted from the figure, there is a discrepancy between the NPDES discharge values and the subsurface disposal discharge values for the months of May and June 1978. Prior to July 1978, the NPDES discharge values were based on an average of the instantaneous values. Because these instantaneous rates were not weighted in accordance with time or period of discharge, the extrapolated monthly values are much higher than the average monthly flow.

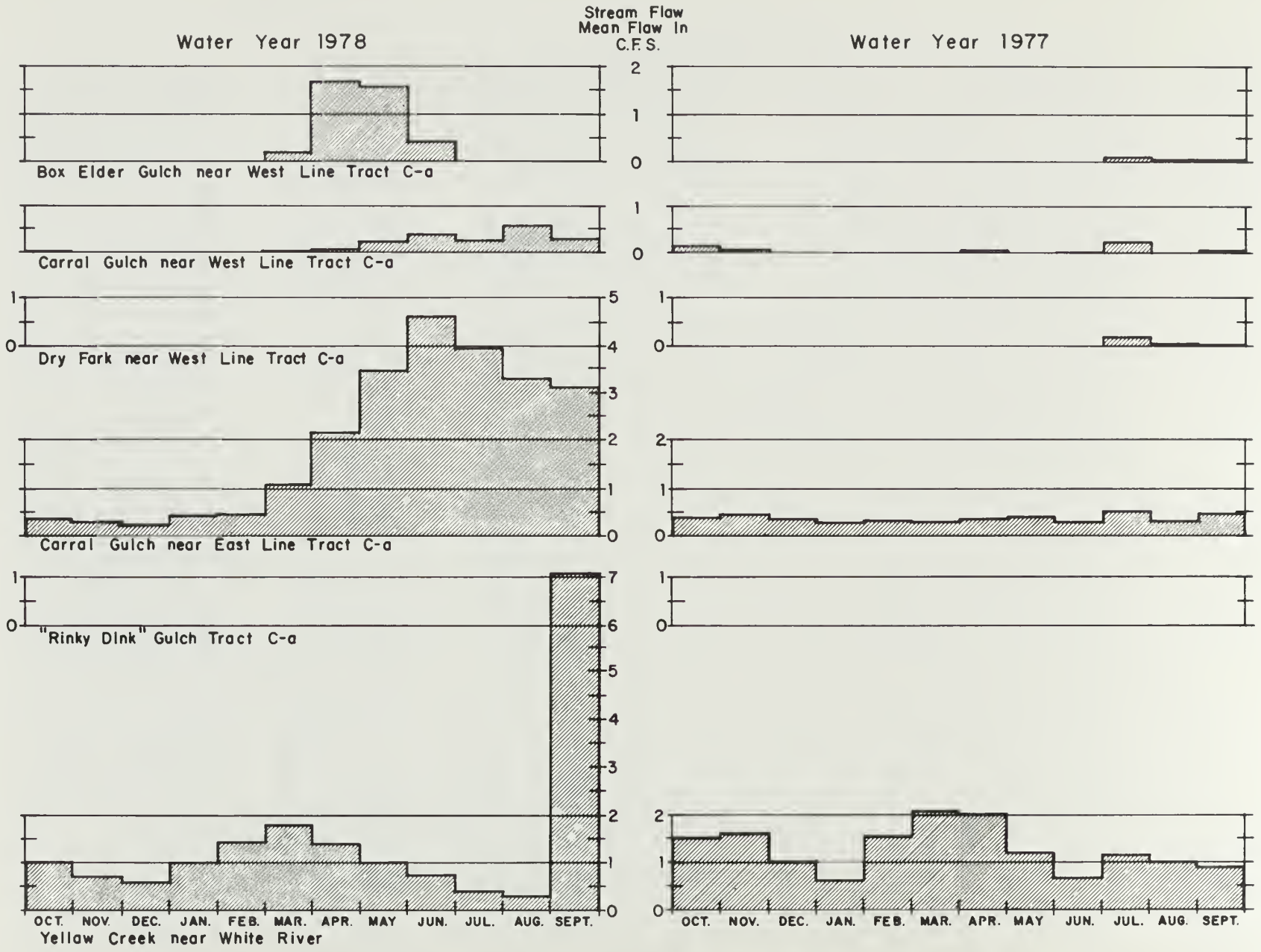
Water Year 1978
Stream Flow
Mean Flow In
C.F.S.
Water Year 1977
Box Elder Gulch near West Line Tract C-a
Carral Gulch near West Line Tract C-a
Dry Fork near West Line Tract C-a
Carral Gulch near East Line Tract C-a
"Rinky Dink" Gulch Tract C-a
Yellow Creek near White River
OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEPT.

FIGURE 5-2. Monthly Mean Flows at Six Surface Water Gaging Stations, Water Years 1977 and 1978

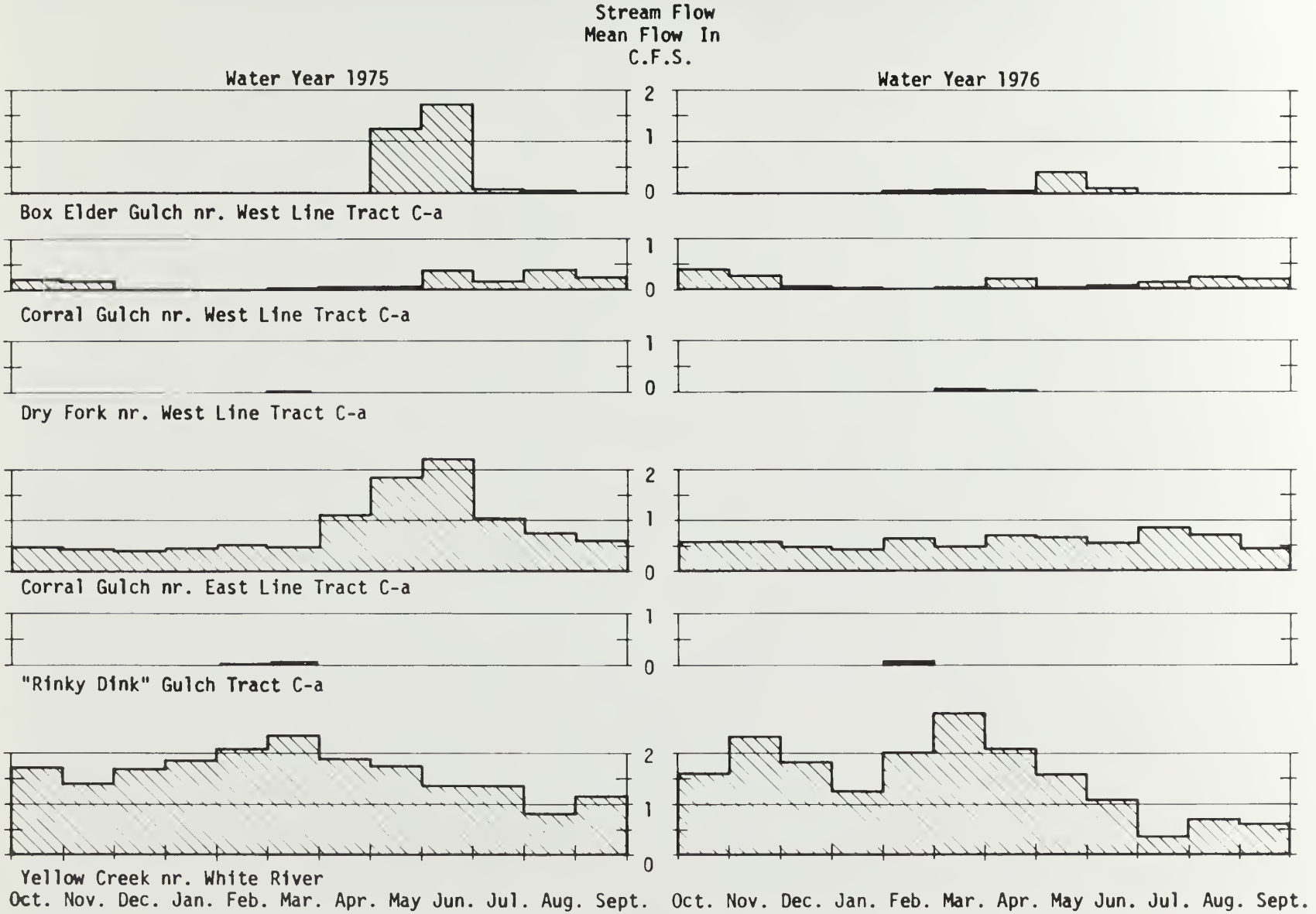
Stream Flow
Mean Flow In
C.F.S.
Water Year 1975
Water Year 1976
2
1
0
Box Elder Gulch nr. West Line Tract C-a
Corral Gulch nr. West Line Tract C-a
Dry Fork nr. West Line Tract C-a
Corral Gulch nr. East Line Tract C-a
"Rinky Dink" Gulch Tract C-a
Yellow Creek nr. White River
Oct. Nov. Dec. Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sept.
Oct. Nov. Dec. Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sept.

FIGURE 5-2a. Monthly Mean Flows at Seven Gaging Stations, Water Years 1975 and 1976

TABLE 5-3 ANNUAL RUNOFF IN ACRE-FEET

STATION	WATER YEAR 1975	WATER YEAR 1976	WATER YEAR 1977	WATER YEAR 1978
Dry Fork near west line Tract C-a	0.2	4.3	11.4	Dry
Corral Gulch near west line Tract C-a	96.7	98.5	30.8	107.1
Box Elder Gulch near west line Tract C-a	182.8	34.8	13.9	228.4
Rinky Dink Gulch near east Tract C-1	0.6	2.3		
Corral Gulch near east line Tract C-1	626.2	418.1	262.8	1399
Stake Springs Draw near Confluence with Corral Gulch	0.0	15.5		
Yellow Creek near White River	1158.7	1103.1	925.7	1044.6

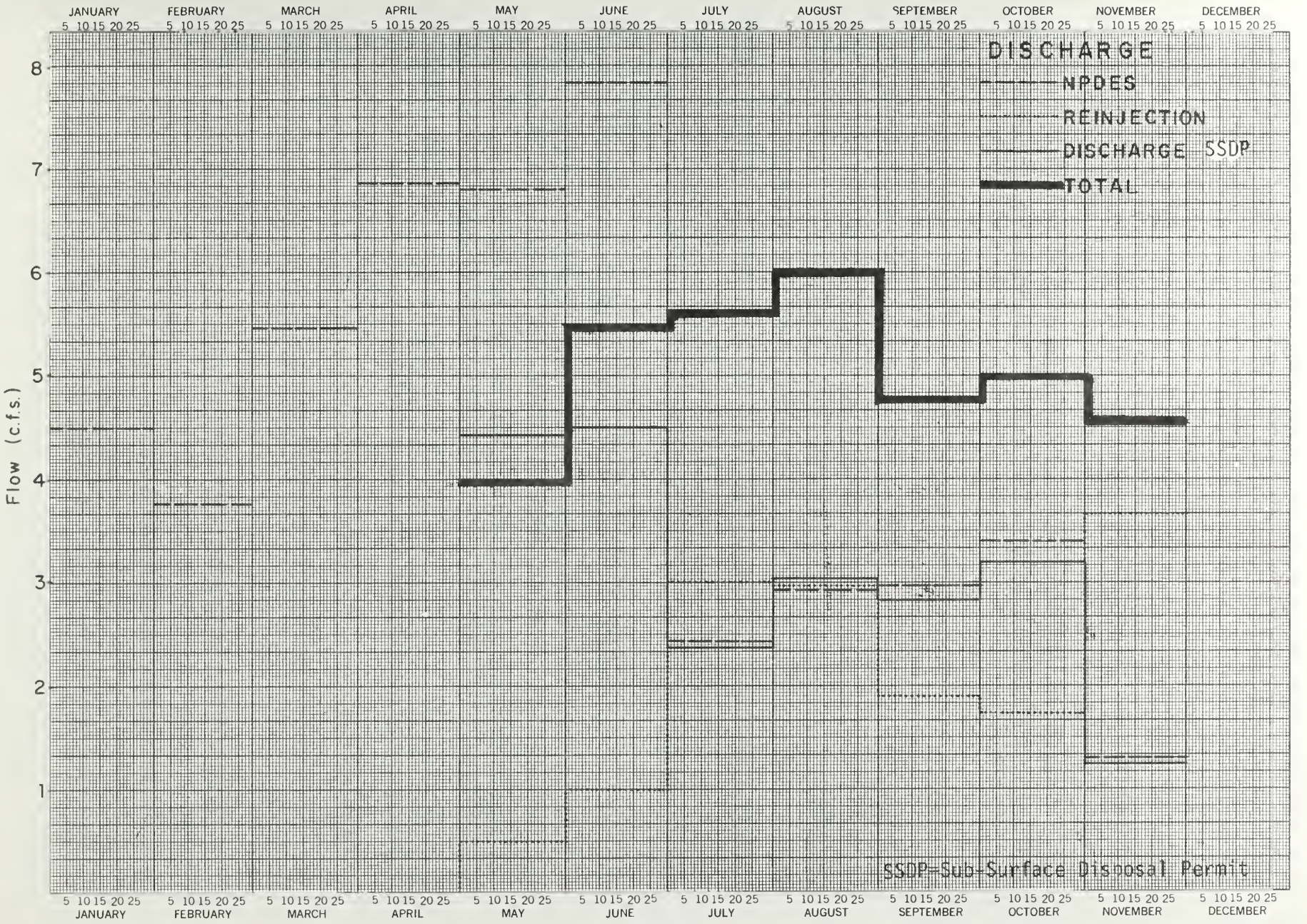

FIGURE 5-3

1978

MDP DEWATERING DISCHARGES

In order to quantify the difference between the amount of water entering Tract C-a and the amount leaving Tract C-a via surface water, the sum of the inflows from Dry Fork, Box Elder Gulch, Corral Gulch and the dewatering discharge were subtracted from the outflow at the Corral Gulch East gaging station. The results of this calculation, shown in Figure 5-4, indicated that, during the period of May 1977 through November 1978, approximately 50 acre-feet either consumed, evaporated, or recharged into the alluvial aquifer system.

After the first release of water into Corral Gulch from the dewatering program, the flow of water across the drainages of Tract C-a peaked dramatically. The pattern of surface water inflows and outflows across the drainages identified during baseline were repeated in 1977 and the spring of 1978. During this four-year period, snowmelt runoff was the most important contributor to surface water flows. Continued flows from storage within the alluvial aquifer produced discharges after peak surface flows has been registered. In June 1978, a new high of 225 acre-feet discharge was calculated.

b. Chemical Parameters - Summaries of water quality data collected at Box Elder Gulch near the west line of Tract C-a, Corral Gulch near the west line of Tract C-a, Corral Gulch near the east line of Tract C-a, and Yellow Creek near the White River for the period of June 1976 through October 1978 are presented in Appendix 5-1.1. As shown on Table 5-2. no flow was recorded at the Dry Fork or Rinky Dink gaging stations. Individual sample analyses are included in Appendix 5-1.2.

The null hypothesis (there is no significant difference in the chemical composition of the surface water at control and treatment sites on the same drainage) is only valid provided there is continuous flow between the stations. Since these streams are ephemeral and there is not continuous flow, a new null hypothesis (there is no significant difference between the chemical composition of the surface water reported in the baseline data and the chemical composition of the surface water reported in the MDP data) was tested, using the baseline data as the control group and the MDP data as the treatment group.

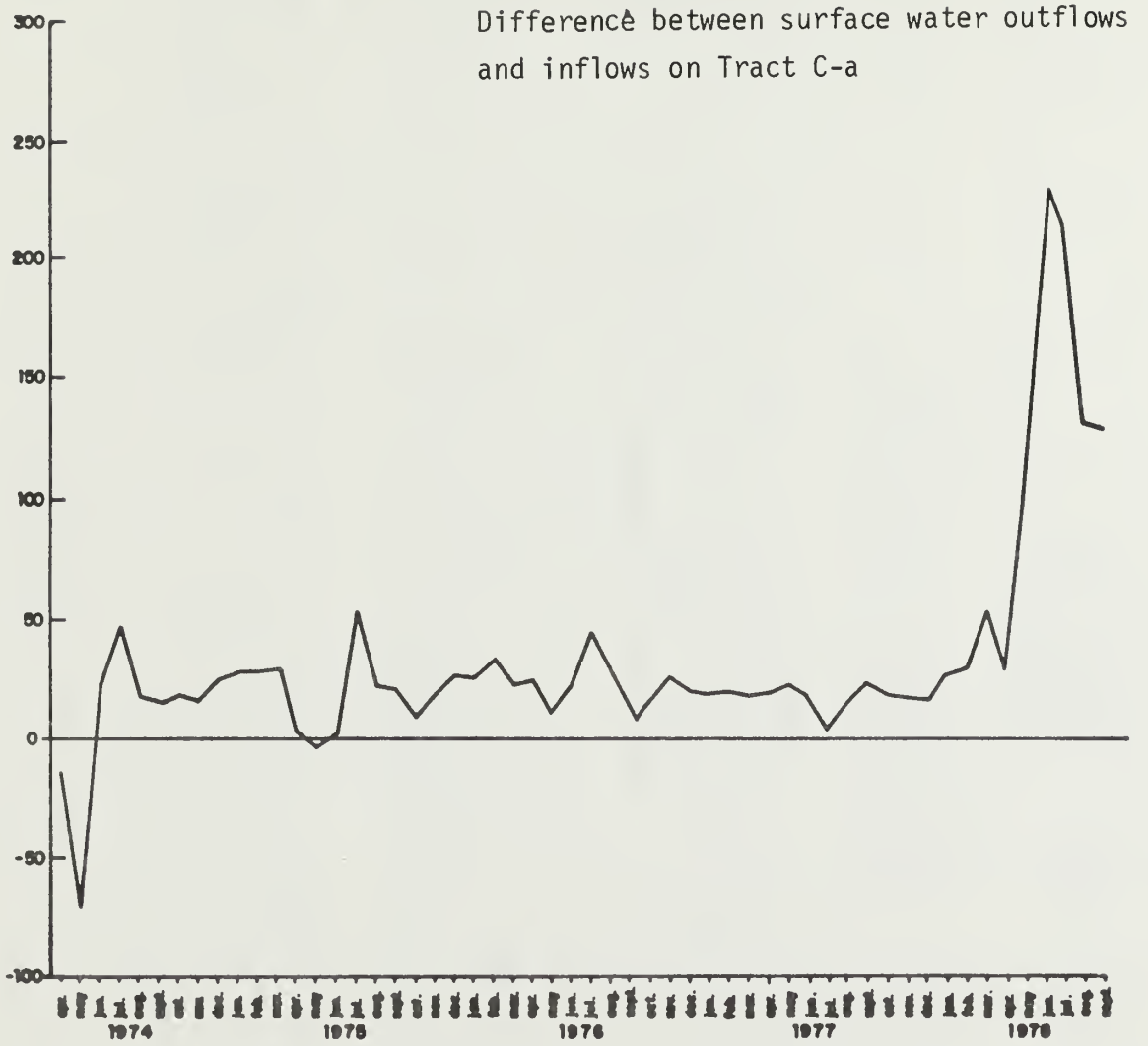

FIGURE 5-4 Comparison of Surface Water Inflows and Outflows 1974-1978, Tract C-a

The means of the control group and the treatment group were tested to determine whether there is any significant difference between them or whether the difference is merely due to chance. The t-test, whose formula is given below, was used to compare these means.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$\bar{x}_1$ = mean of control group
$\bar{x}_2$ = mean of treatment group
s_1 = standard deviation of control group
s_2 = standard deviation of treatment group
n_1 = number of items in control group
n_2 = number of items in treatment group

The calculated t was then compared with a tabular value of t at the .025 level. If the calculated t had an absolute value less than the tabular value, the null hypothesis was accepted. However, if the calculated value was larger than the tabular value, then the null hypothesis was rejected and anomaly was indicated. The anomaly was analyzed to determine its possible source.

Table 5-4 shows the consituents of the surface water at Corral Gulch East, Corral Gulch West, and Box Elder Gulch gaging stations whose means showed a statistically significant difference at the 95 percent confidence level.

Each of the anomalies for the Corral Gulch East gaging station can be explained by the addition of upper aquifer water to the water type found during the baseline period. Since the change in water quality can be explained, the null hypothesis can be accepted.

The constituents at Corral Gulch gaging station near the west line of Tract C-a which were indicated to be anomalous by the t-test are the same constituents found at the Corral Gulch gaging station near the east line of Tract

C-a. It should be noted however, that the signs of the differences are opposite to those of the downstream Corral Gulch gaging station. There is one exception to this, that is, calcium, where both signs are positive.

The anomalies indicated for the Corral Gulch West gaging station can be explained by a reduction of the amount of water originating from the upper aquifer and/or an increase in the amount of surface water runoff. The data presented on Table 5-3 of this report indicate that surface water runoff did, indeed, increase during water year 1978. The drawdown data presented by the operational monitoring does not appear to indicate that water levels in the upper aquifer in the vicinity of the springs feeding the Corral Gulch surface water gaging station should have been affected. Therefore, the null hypothesis is corroborated again by this explanation.

The anomalies indicated on Table 5-4 for the Box Elder Gulch surface water gaging station are most likely a result of the high surface water flows which occurred during water year 1978. The annual runoff during water year 1978 was approximately equal to the sum of the annual runoff from water years 1975, 1976, and 1977. In that the sign or nature of the variation indicated by the t test is not consistent, it is felt that these anomalies are due to natural phenomena. Therefore, the null hypothesis is accepted.

Surface water quality data at any given station suggested that the variation in concentrations of a chemical component was not totally independent, but that there were interrelationships between chemical parameters. In order to determine which of the chemical parameters were correlated with each other, correlation analyses were run on log-transformed data of selected chemical parameters (pH was already in log form). Figures 5-5 through 5-9 summarize these analyses. These summary matrices show significant correlations at the 5 percent confidence level with a "+" for direct correlation (i.e., when concentration of one parameter increases, the other one also tends to increase), and a "-" for inverse correlation. Results are presented separately for four stations, Corral Gulch West, Box Elder Gulch, Corral Gulch East, and Yellow

FIGURE 5-5 BOX ELDER GULCH WATER CONSTITUENT SIGN CORRELATION MATRIX

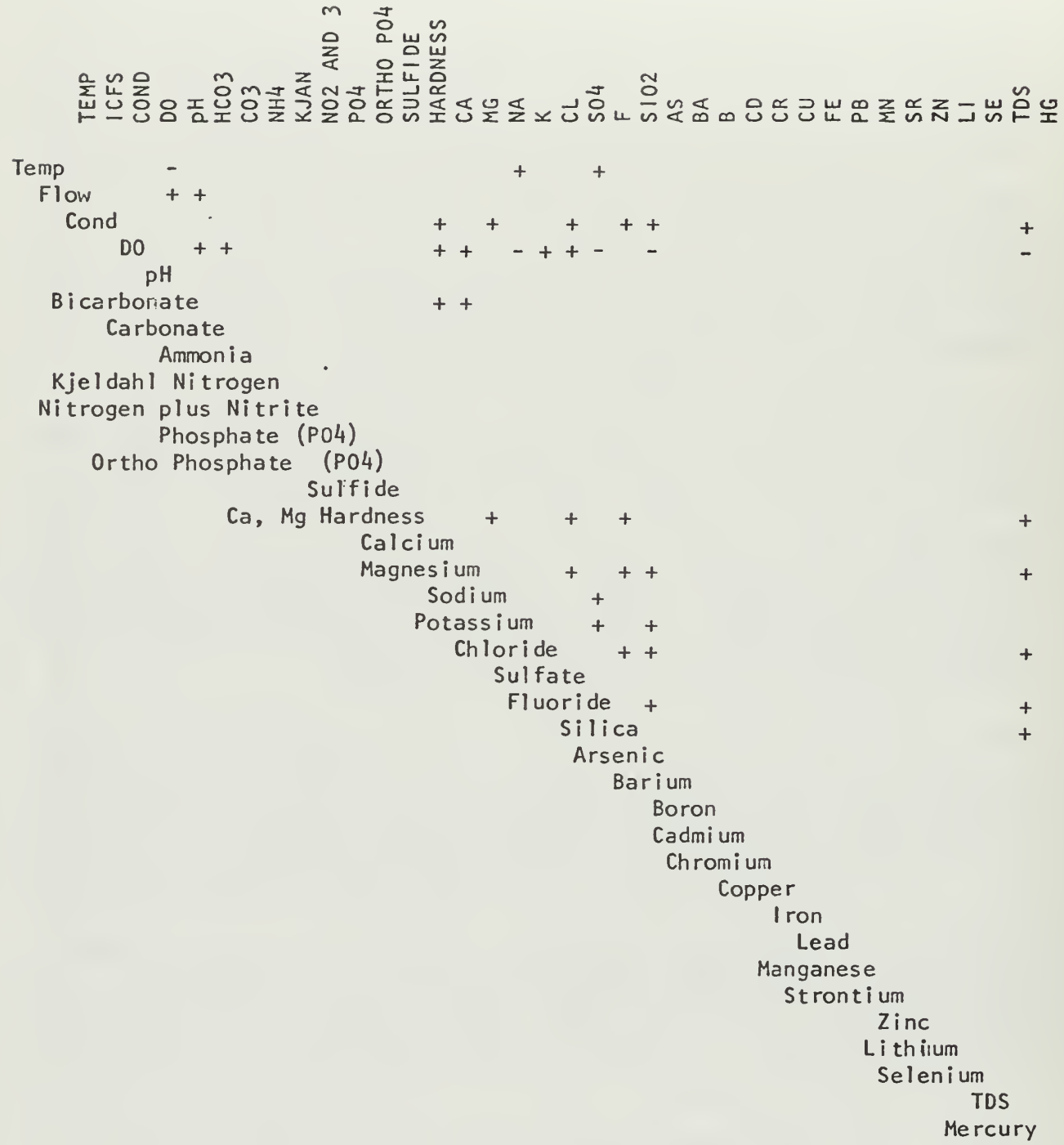

FIGURE 5-6 CORRAL GULCH WEST WATER CONSTITUENT SIGN CORRELATION MATRIX

ICFS - Instantaneous Flow (cu ft/sec)

FIGURE 5-7 CORRAL GULCH EAST WATER CONSTITUENT SIGN CORRELATION MATRIX

ICFS - Instantaneous Flow (cu ft/sec)

FIGURE 5-8 YELLOW CREEK WATER CONSTITUENT SIGN CORRELATION MATRIX

ICFS - Instantaneous Flow (cu ft/sec)

FIGURE 5-9 COMBINED STATIONS WATER CONSTITUENT SIGN CORRELATION MATRIX

ICFS - Instantaneous Flow (cu ft/sec)

Creek, while Corral Gulch West, Corral Gulch East and Box Elder Gulch are combined in the matrix in Figure 5-9.

Box Elder Gulch near the west line of Tract C-a flows only during snowmelt or intense rainfall events, so correlations at this station primarily represent surface runoff and some interaction with alluvium and possible interflow discharge. No major changes occurred at this site during the monitoring period.

Water entering the tract at Corral Gulch showed a higher positive correlation among the major constitutents with conductivity, and with total dissolved solids (TDS) during the MDP than was demonstrated among baseline constituents. The relationship between hardness/chlorine and sulfate/fluoride changed from a negative to a positive correlation.

TABLE 5-4. STUDENT'S t-TEST RESULTS, INDICATING THOSE CONSTITUENTS WHICH WERE SIGNIFICANTLY DIFFERENT IN A COMPARISION OF BASELINE DATA AND MDP DATA, DECEMBER 1, 1977 - NOVEMBER 30, 1978.

	Box Elder	Corral West	Corral East
Conductivity	+	+	+
Alkalinity	+	+	-
Bicarbonate	+	+	-
Hardness	-	+	-
Calcium	+	+	+
Magnesium		+	-
Sodium	-	+	-
Sulfate	-	+	-
Silica	+	+	-
TDS	+	+	-

\+ indicates mean from baseline greater than mean from MDP

\- indicates mean from baseline less than mean from MDP

Correlation analysis of the Corral Gulch East sampling station data revealed weaker relationships among chemical constitutents during the MDP than during the baseline period. This trend is probably related to the discharge of water removed from dewatering wells directly to Corral Gulch.

The most significant trend noted at this site was the reversal of the positive correlation between calcium (Ca) and flow to a negative correlation. The relationships between calcium and fluoride, and between sodium and and silica changed from negative to positive in the current year. Further, recent data established positive correlations between temperature and bicarbonate (HCO_3), and magnesium (Mg) and TDS. The causes of these changes are not fully understood. Evaluation of the data will continue in an effort to pinpoint source of change and to assess the effect of these changes on the hydrologic system.

B. Springs and Seeps

1. Objectives - The objective of monitoring and observing major springs and seeps during the MDP is to determine if spring and seep flows and conductivity are affected by mining and operation activities.

2. Methods - The methods followed for collection of these data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion - Table 5-5 presents a summary of the data collected from the springs and seeps during the current reporting period. Corral Gulch Spring and Seep No. 1, Spruce Gulch Spring and Seep No. 2, and Maverick Springs, Spring and Seep No. 3 were inaccessible during the months of December and April due to the snow pack. Stake Springs Draw Spring and Seep No. 5 were also inaccessible during the month of December. The locations of the springs and seeps are shown on Figure 5-10.

TABLE 5-5. SUMMARY OF SPRING AND SEEP SAMPLING SCHEDULE AND FLOW

Location		1977 Dec	1978 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
#1	Cathedral Bluffs	I				I		X S			X S	
#2	Spruce Gulch	I				I		X S			X S	
#3	Mavarick Spring	I				I		X S			X S	
#5	Stake Springs Draw	I				X S		X S			D	
#8	Box Elder Gulch	X	X S			X S		X S			D	
#14	84 Ranch		X S			X S		X S			X S	

X = Flow recorded at time of collection

S = Sample collected

I = Inaccessible

D = Dry

Table 5-6 compares the maximum and minimum conductivity readings from the baseline to those data collected during the MDP period. None of the values were noted to have changed by more than 20 percent, with the exception of the minimum conductivity at Spring and Seep No. 14. This new low reading of 875 micromhos per centimeter was recorded in April 1978. This low reading is due, in part, to the snowmelt runoff and to the discharge from the dewatering operation. Figures 5-11 through 5-34 show the flow, temperature, conductivity, and pH data for the six springs and seeps during the monitoring period.

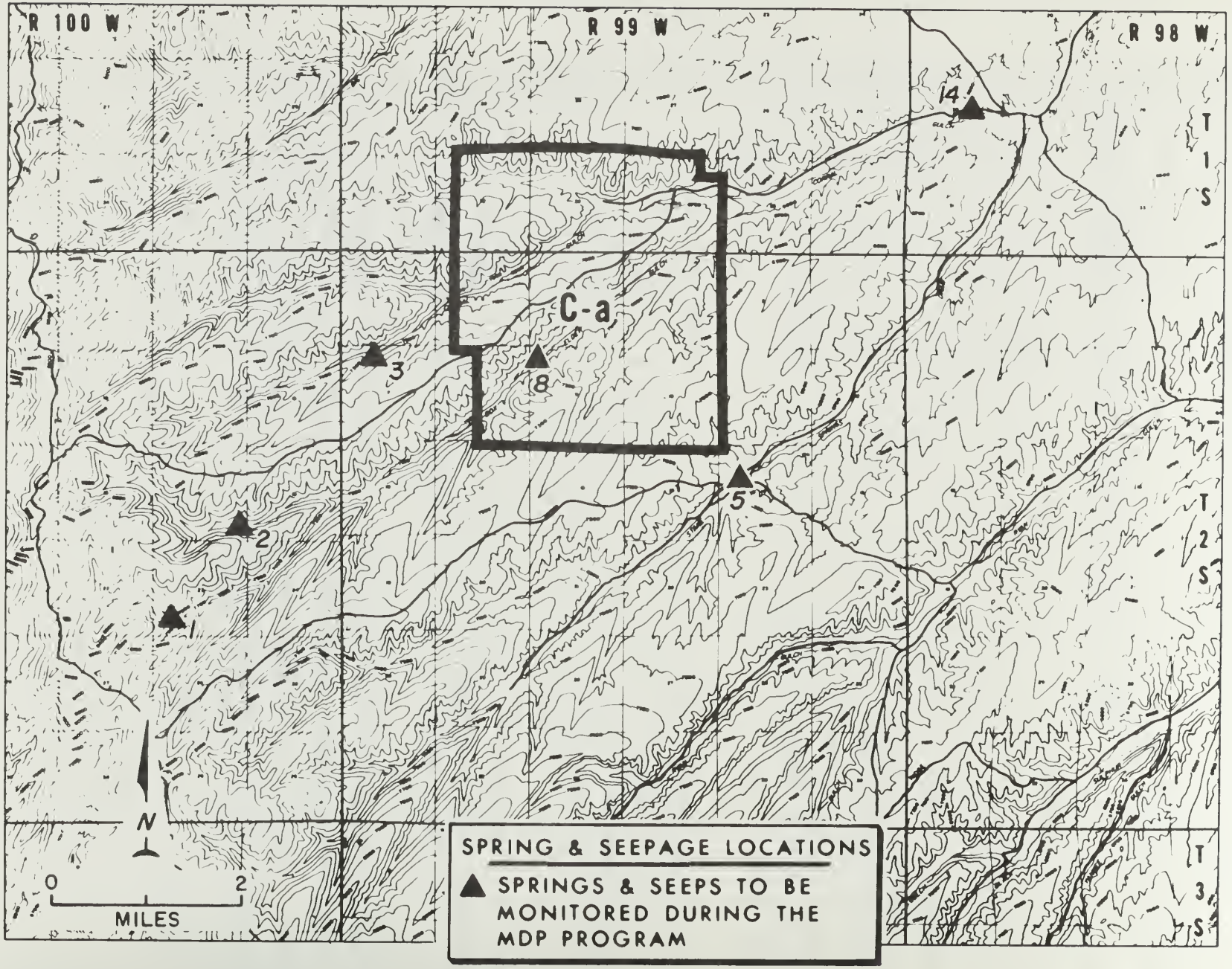

Figure 5-10. Locations of Springs and Seeps Monitored During the MDP.

TABLE 5-6. COMPARISON OF BASELINE AND MDP CONDUCTIVITY DATA FOR SPRINGS AND SEEPS, TRACT C-a

LOCATION	BASELINE MAX.	BASELINE MIN.	MDP MAX.	MDP MIN.
Spring or Seep 1	950	825	910	870
Spring or Seep 2	1200	1000	990	990
Spring or Seep 3	1300	850	1280	1250
Spring or Seep 5	1500	1300	1520	1250
Spring or Seep 8	1100	850	1200	845
Spring or Seep 14	2000	1550	1700	875

5.2 GROUNDWATER

A. Alluvial Aquifers

1. Objectives - The purpose of monitoring the alluvial aquifers during the MDP is to detect changes in the character of the alluvium, determine if the changes are significant, and analyze the changes to ascertain if they are caused by mining or development operations, such as accidental oil spills, breakthrough of the injection water into the lower aquifer, or releases of dewatering water into the alluvial aquifers. An additional objective is to determine if lease and permit requirements are being adhered to.

2. Methods - The methods used to collect these data were described in the RBOSC MDP Monitoring Report 2, except for the following, and are not repeated herein.

A new alluvial hole (G-S S25) was added to the monitoring program. The location of this hole is included in Figure 5-1. This hole is dry but will be measured quarterly and semi-annually for the same parameters as are identified for the quarterly and semi-annual monitoring program.

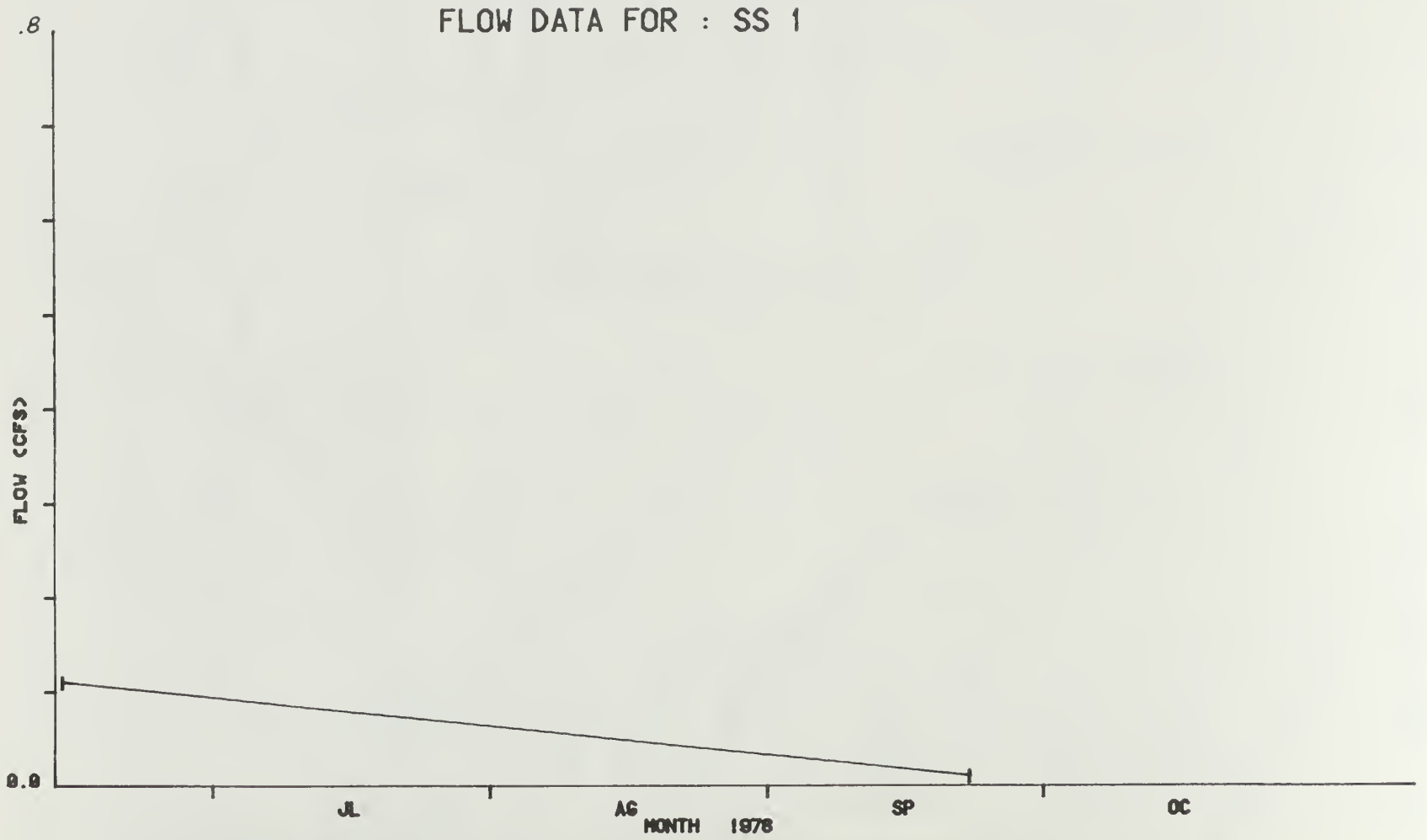

FIGURE 5-11. Flow Data for Spring No. 1 near Tract C-a, 1978

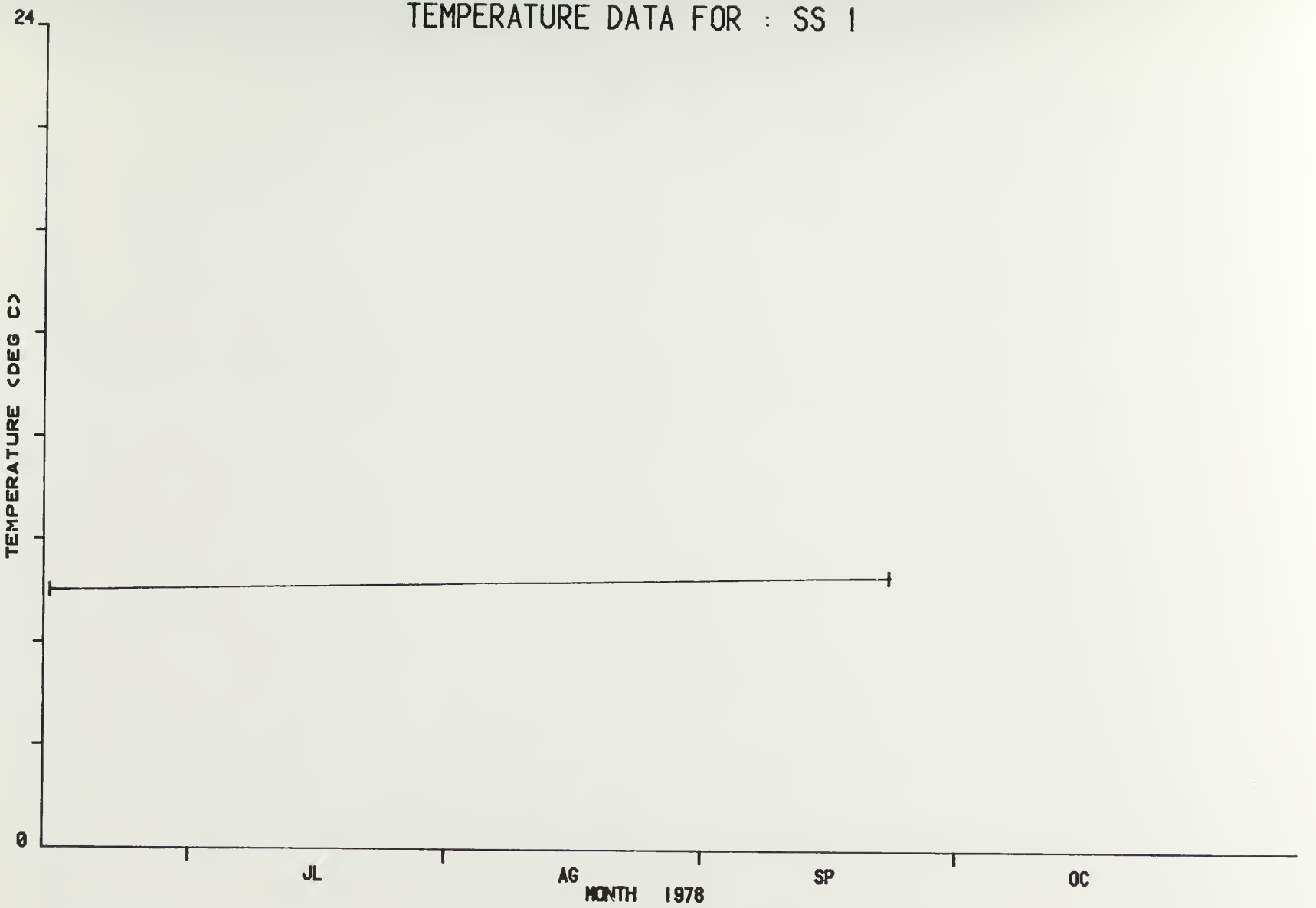

FIGURE 5-12. Temperature Data for Spring No. 1 near Tract C-a, 1978

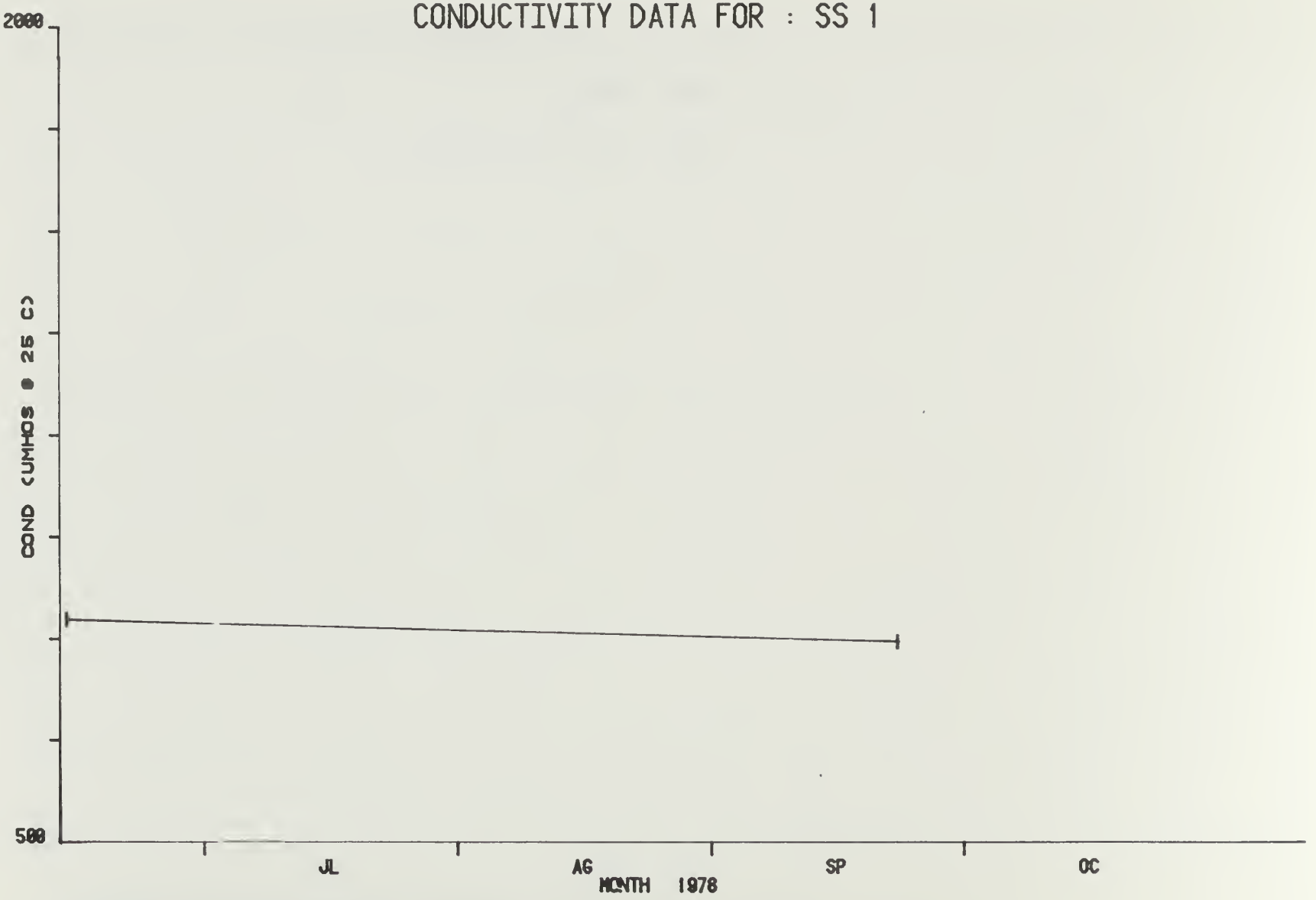

FIGURE 5-13. Conductivity Data for Spring No. 1 near Tract C-a, 1978

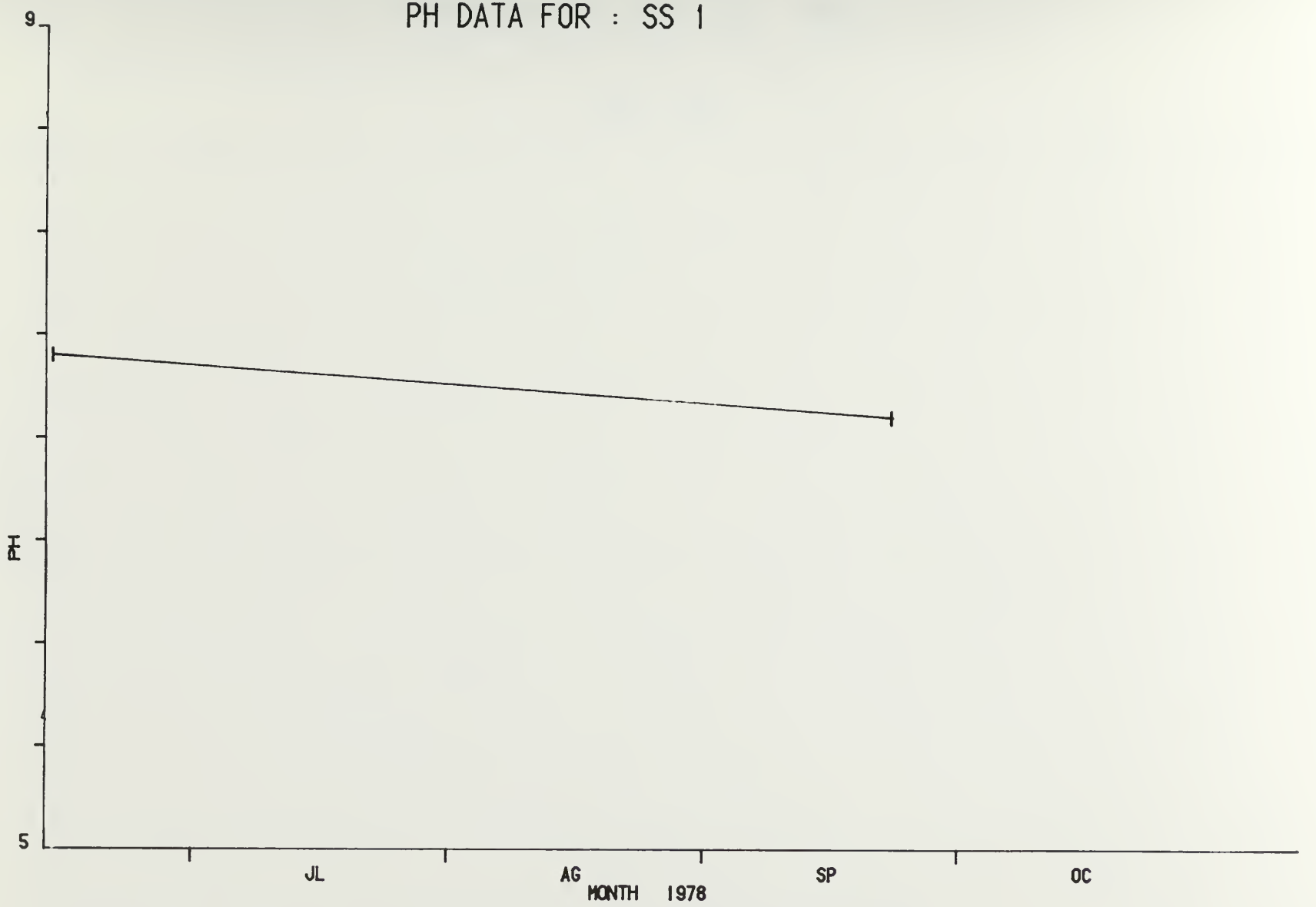

Figure 5-14. pH Data for Spring No. 1 near Tract C-a, 1978

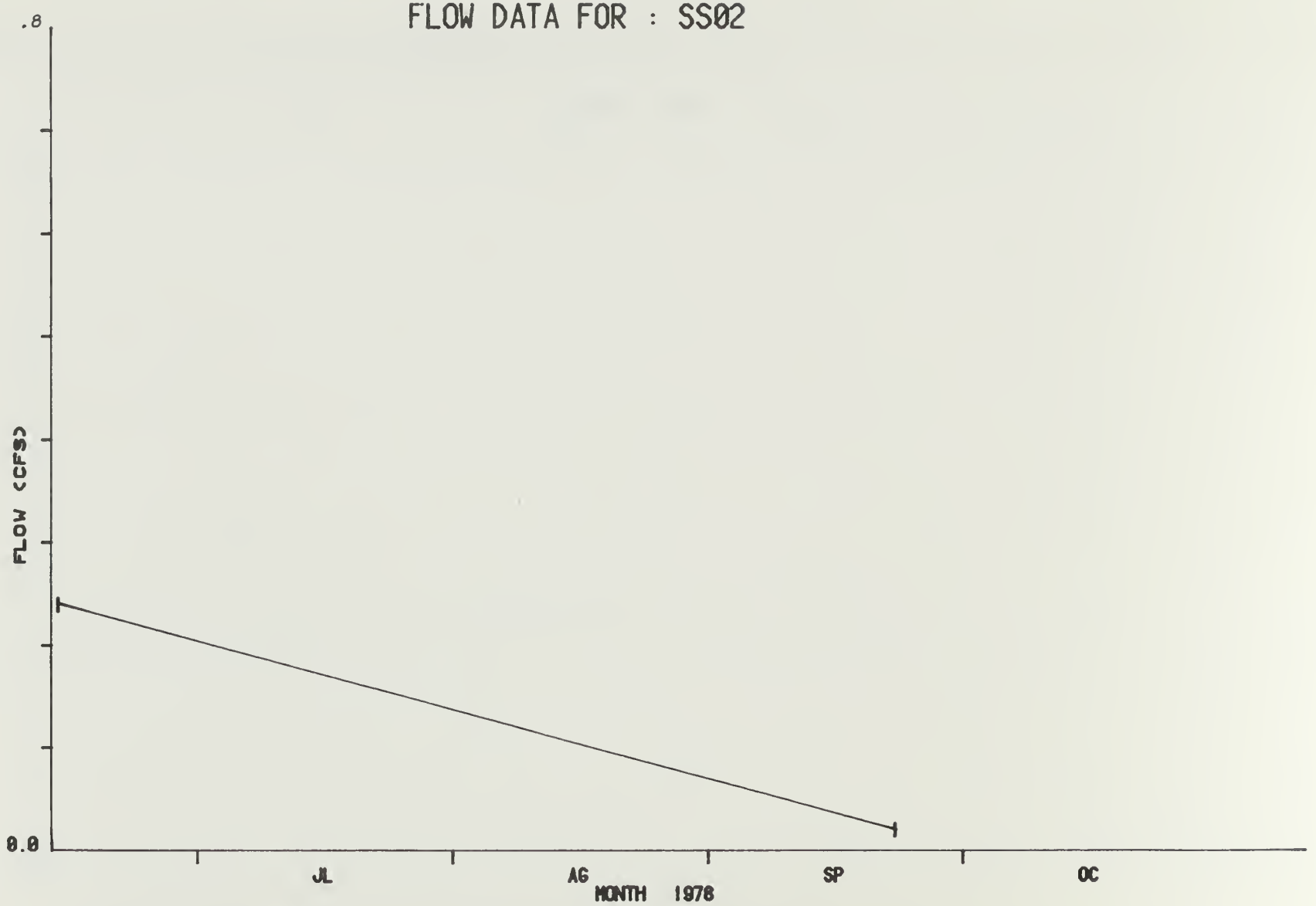

FIGURE 5-15. Flow Data for Spring No. 2 near Tract C-a, 1978

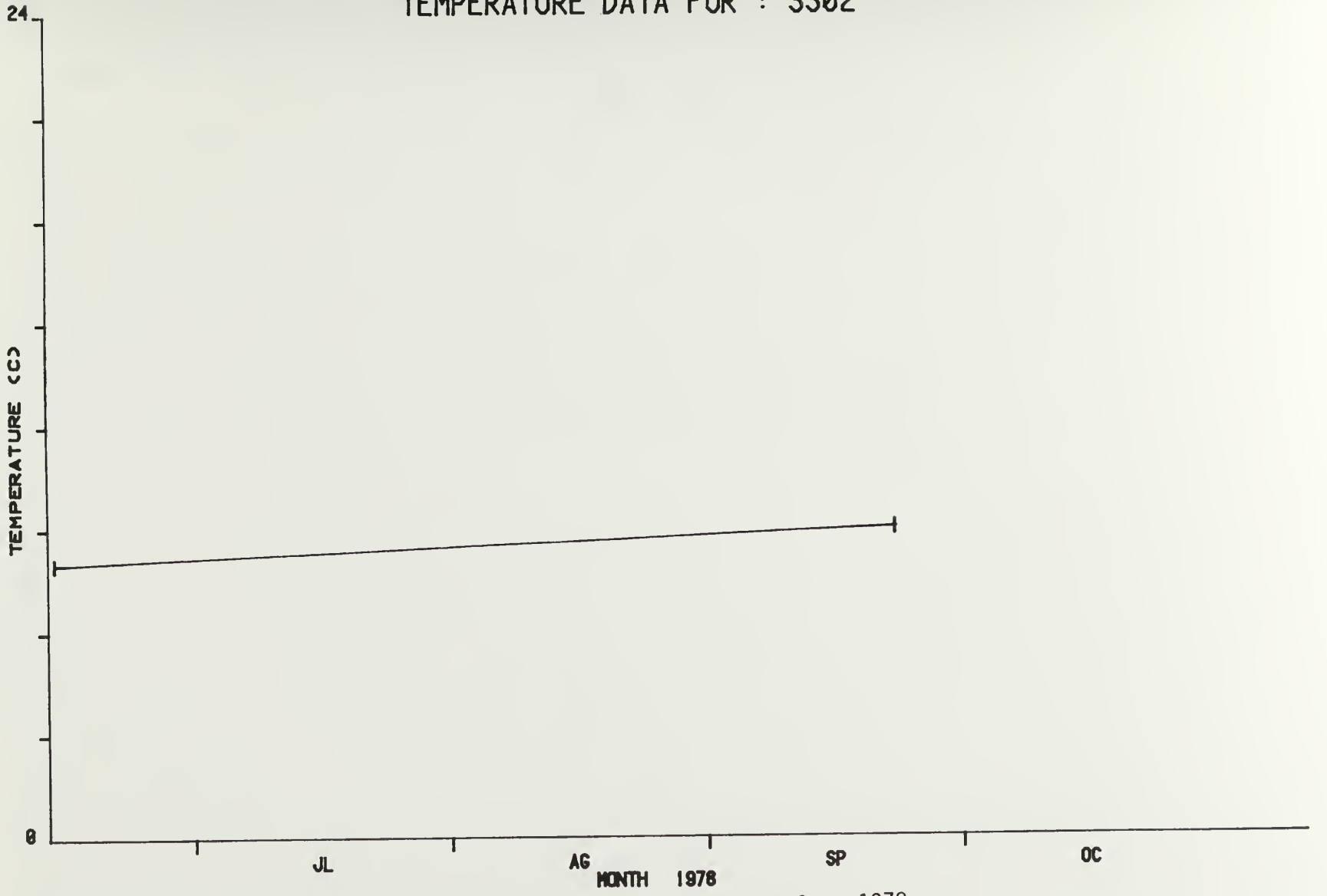

FIGURE 5-16. Temperature Data for Spring No. 2 near Tract C-a, 1978

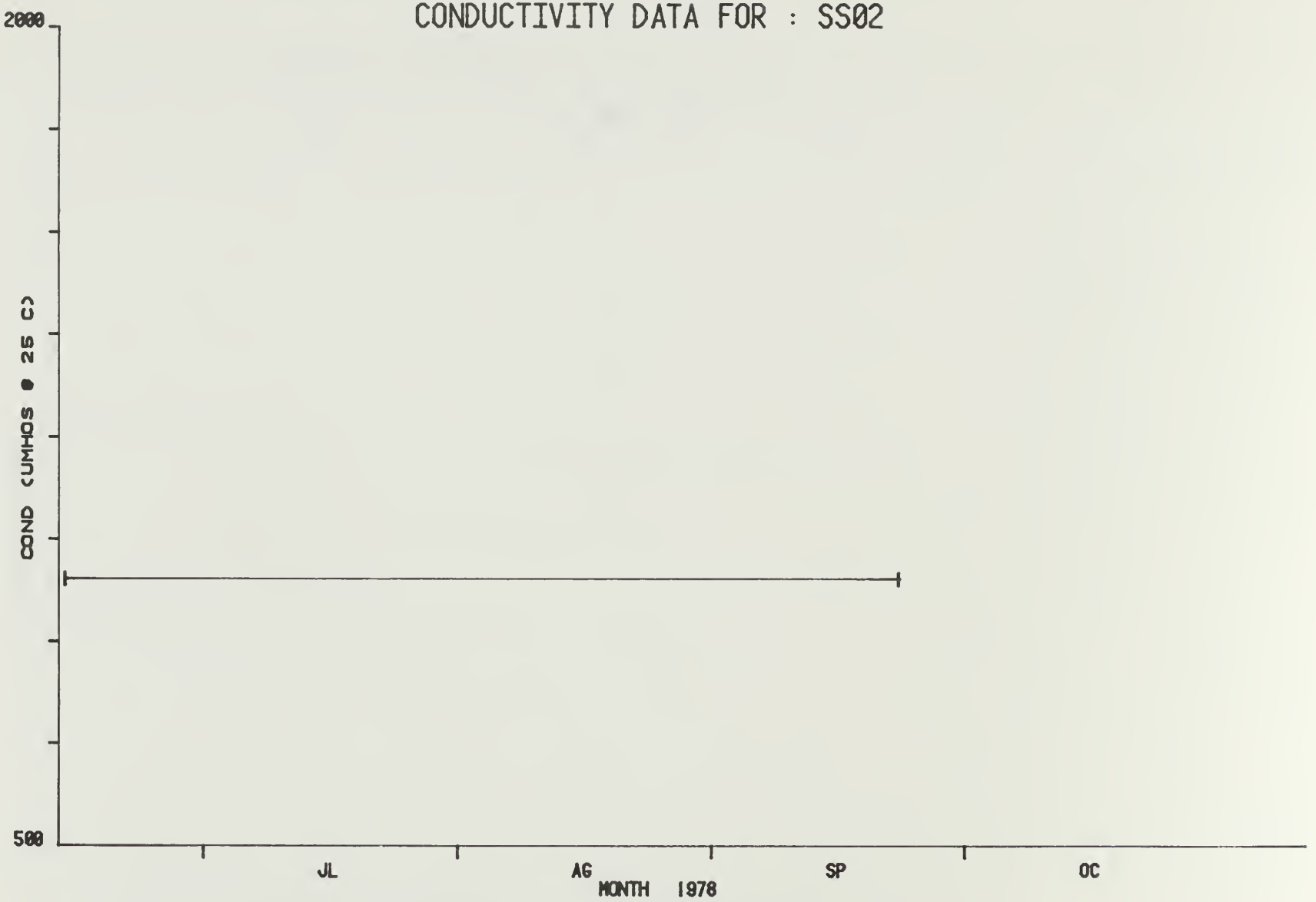

FIGURE 5-17. Conductivity Data for Spring No. 2 near Tract C-a, 1978

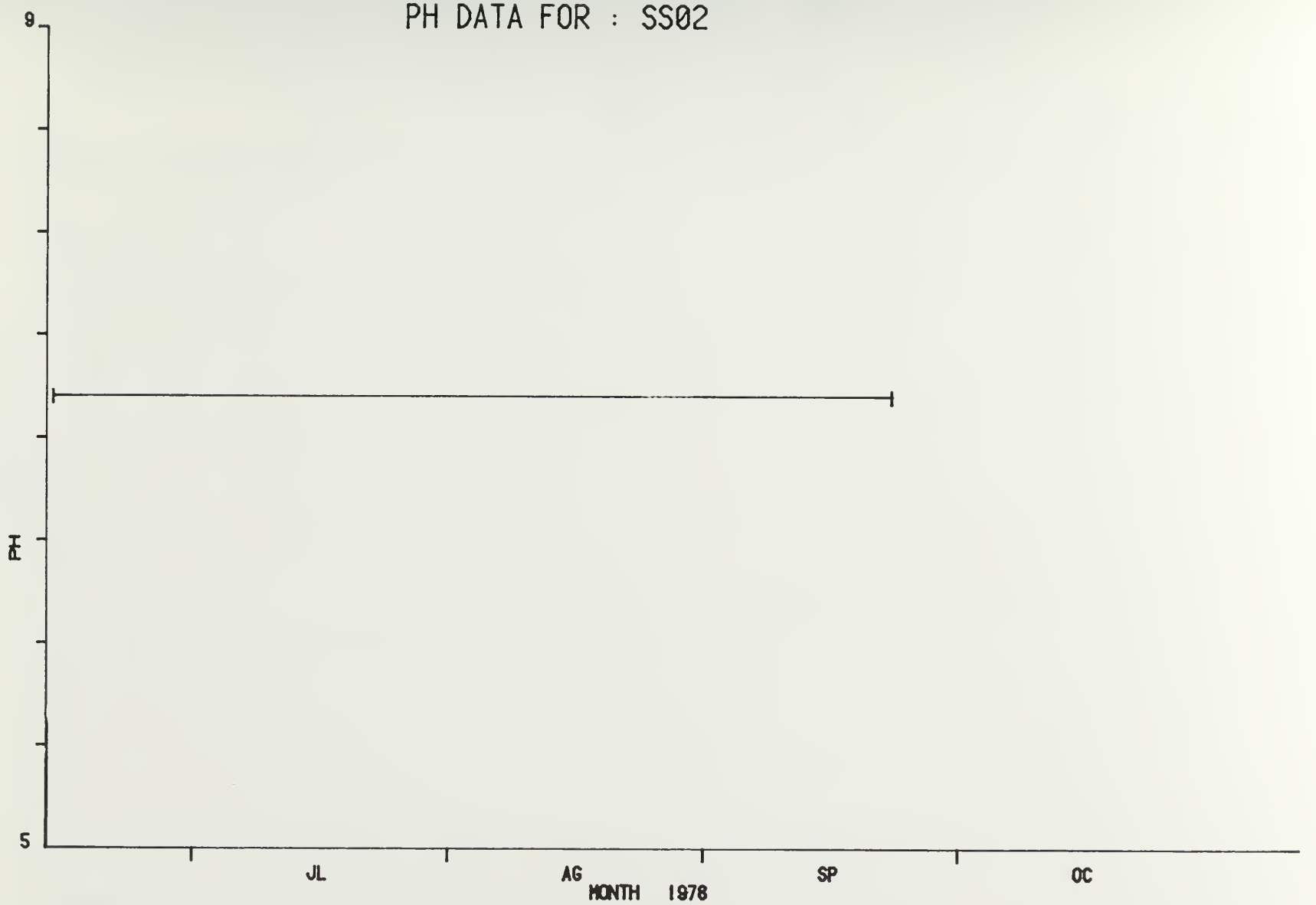

FIGURE 5-18. pH Data for Spring No. 2 near Tract C-a, 1978

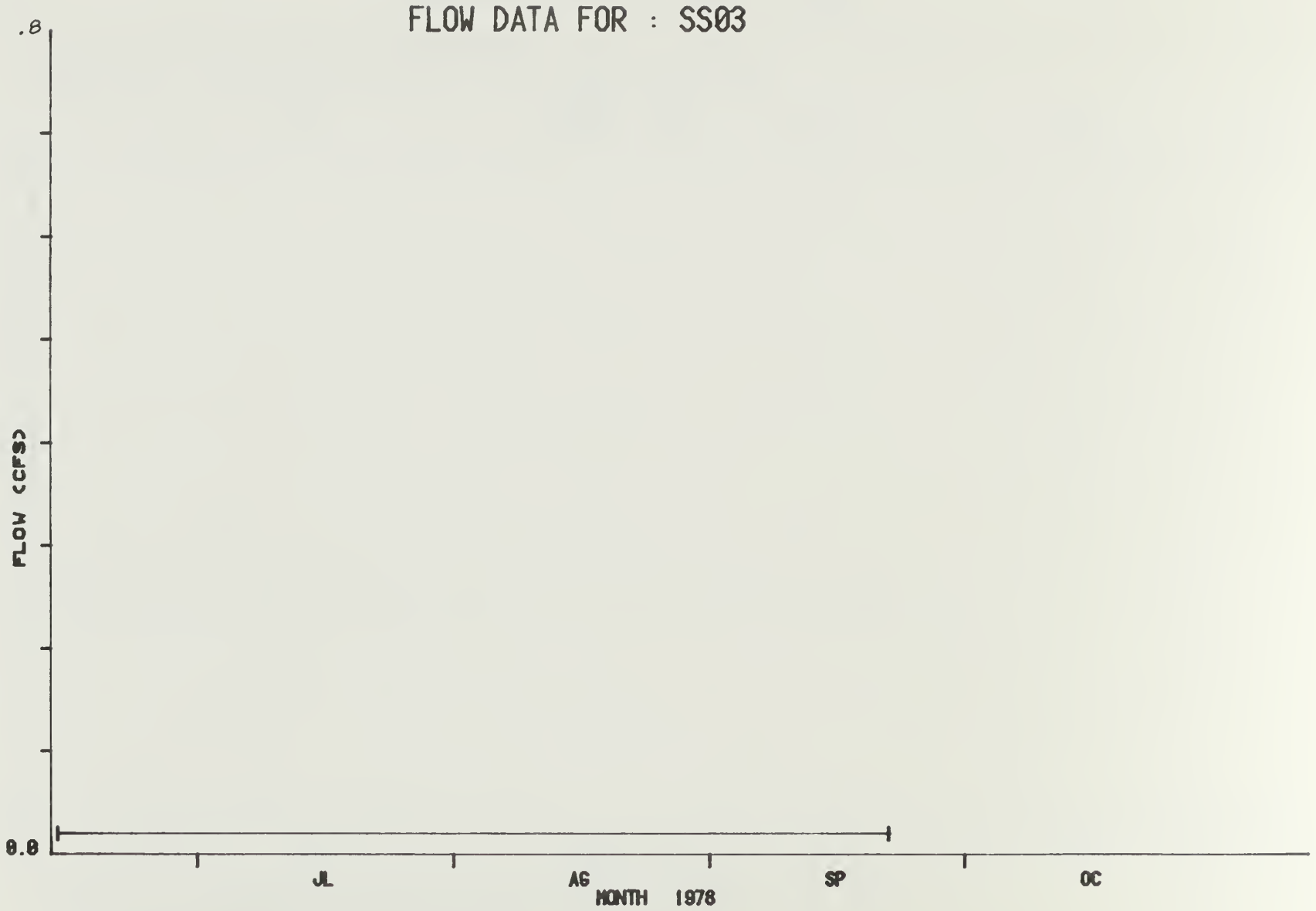

FIGURE 5-19. Flow Data for Spring No. 3 near Tract C-a, 1978

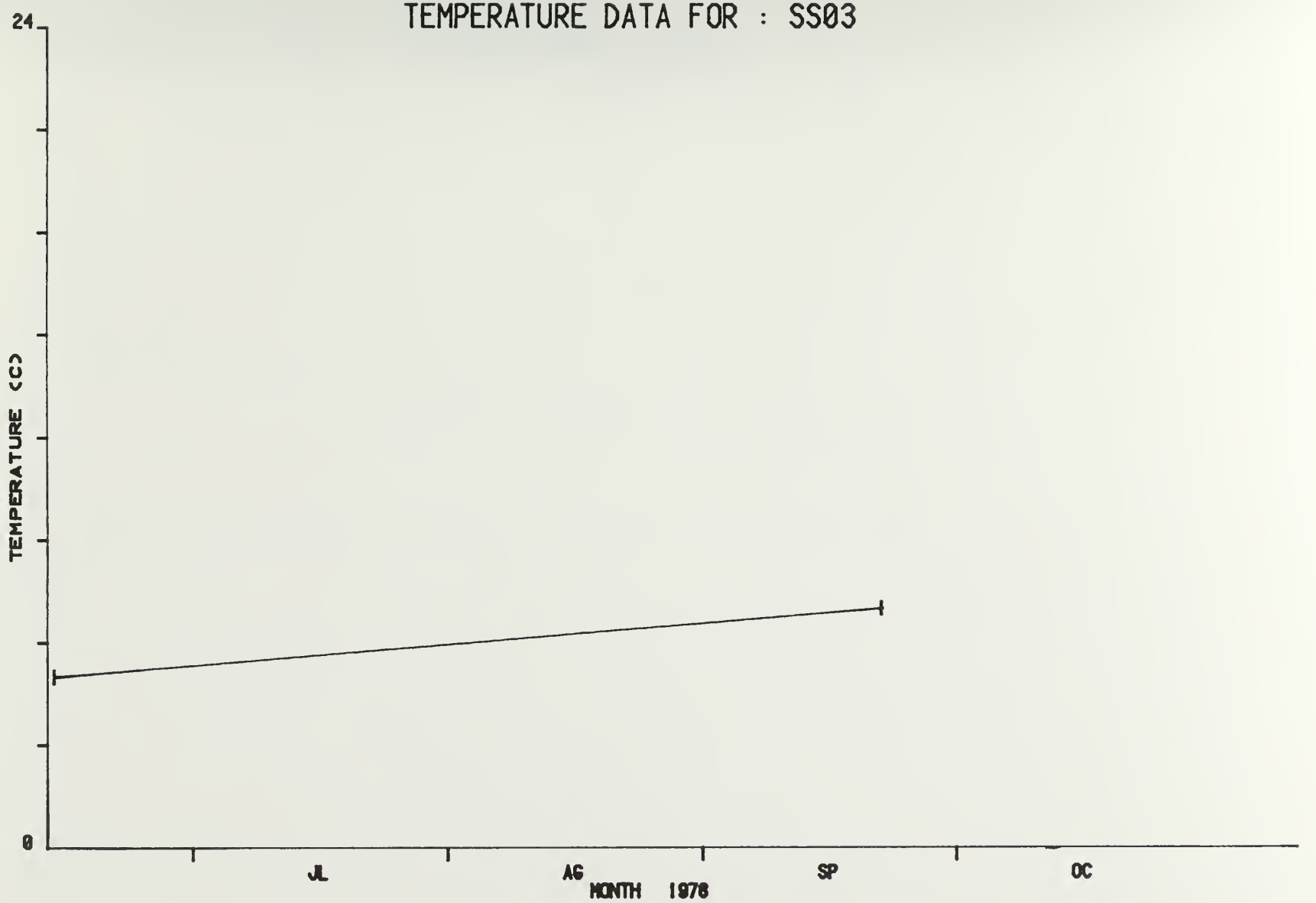

FIGURE 5-20. Temperature Data for Spring No. 3 near Tract C-a, 1978

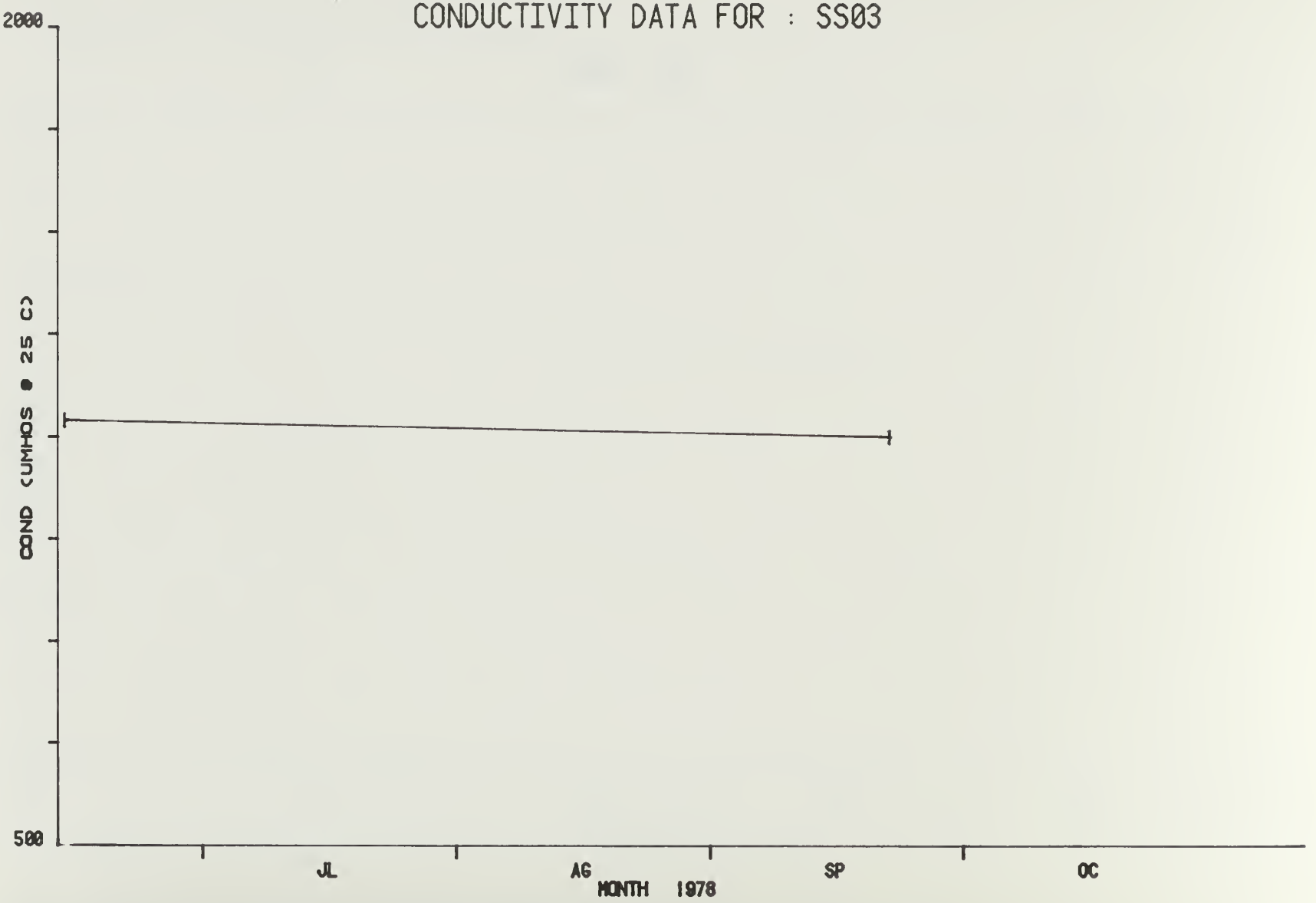

FIGURE 5-21. Conductivity Data for Spring No. 3 near Tract C-a, 1978

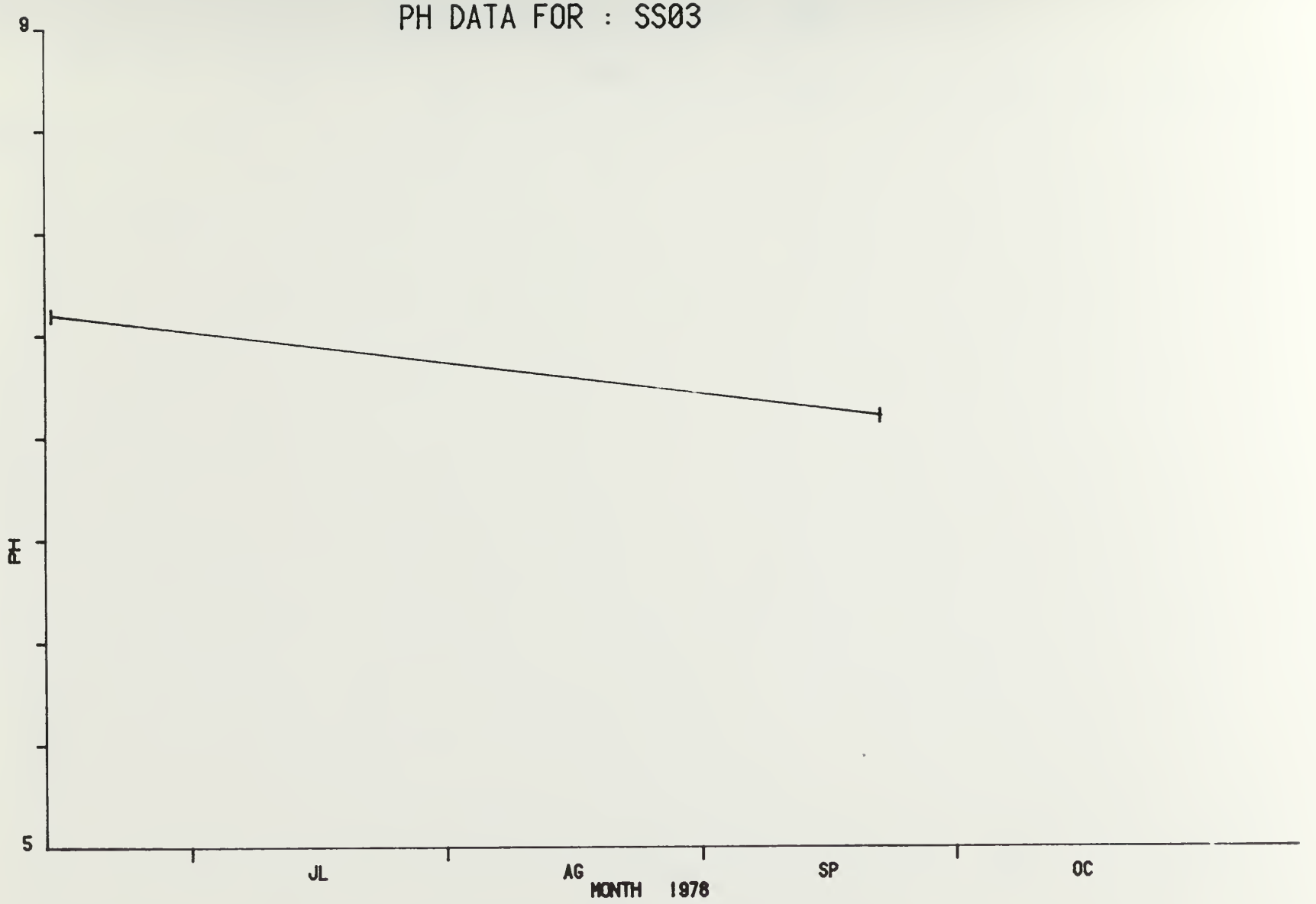

FIGURE 5-22. pH Data for Spring No. 3 near Tract C-a, 1978

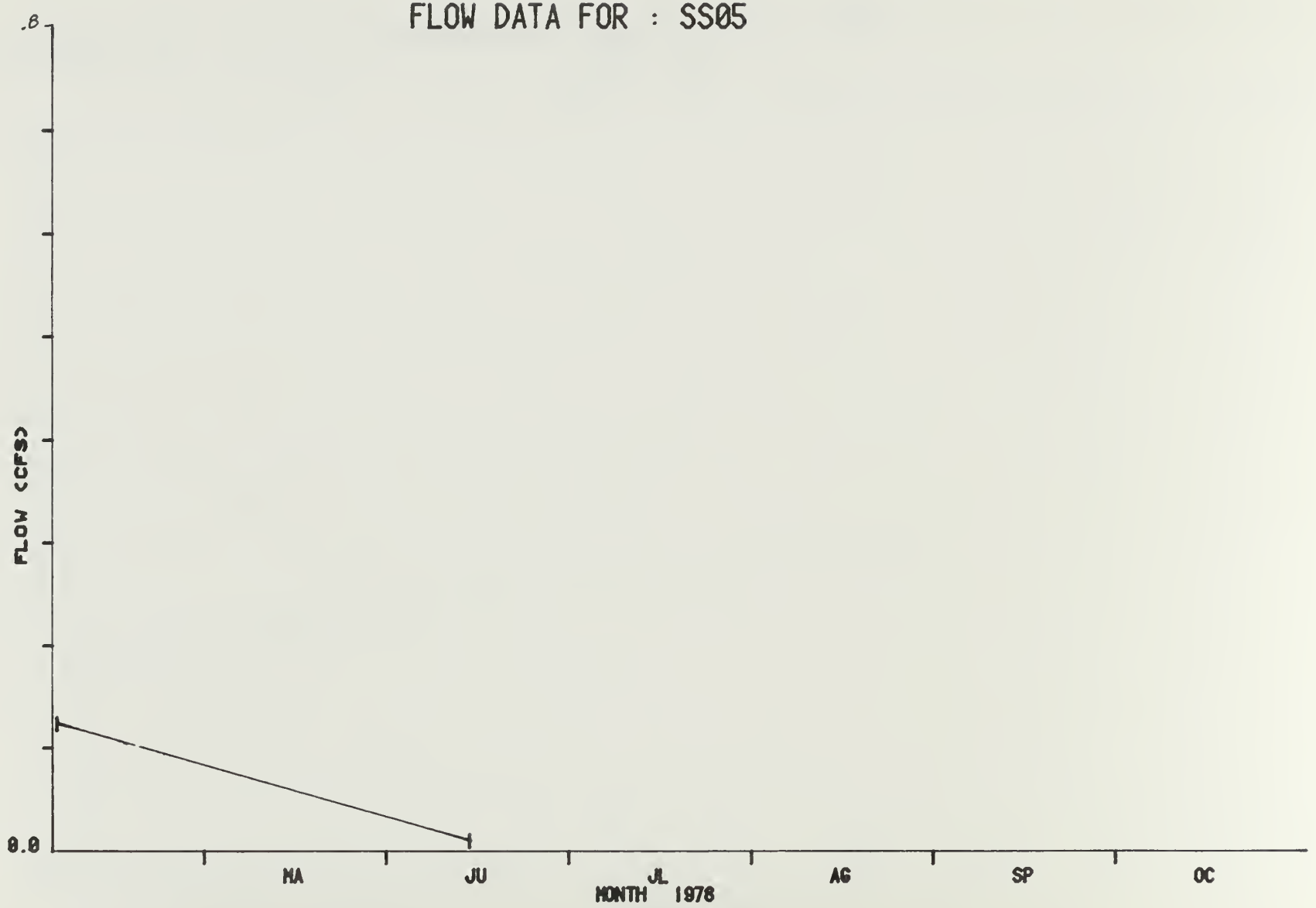

FIGURE 5-23. Flow Data for Spring No. 5 near Tract C-a, 1978

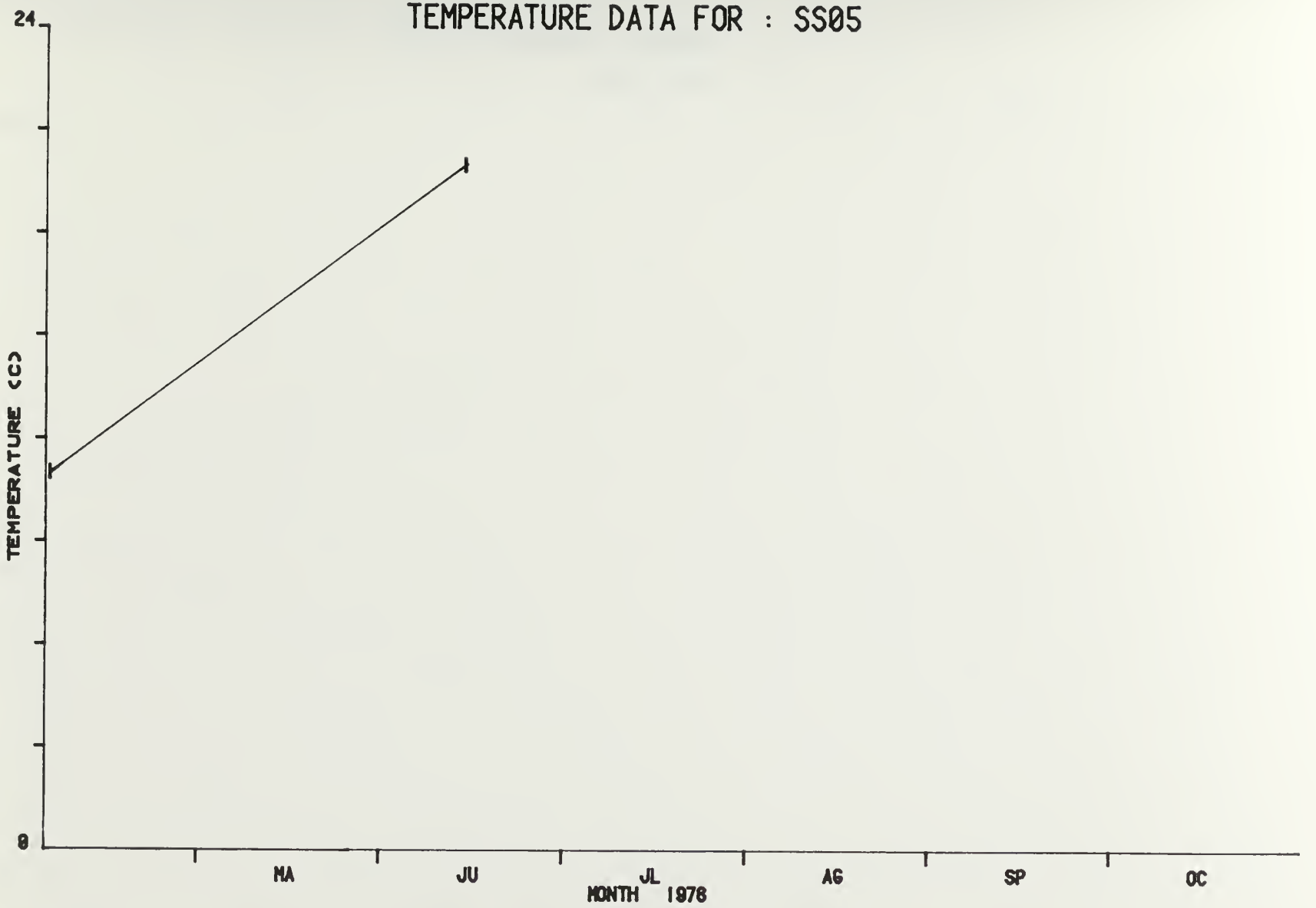

FIGURE 5-24. Temperature Data for Spring No. 5 near Tract C-a, 1978

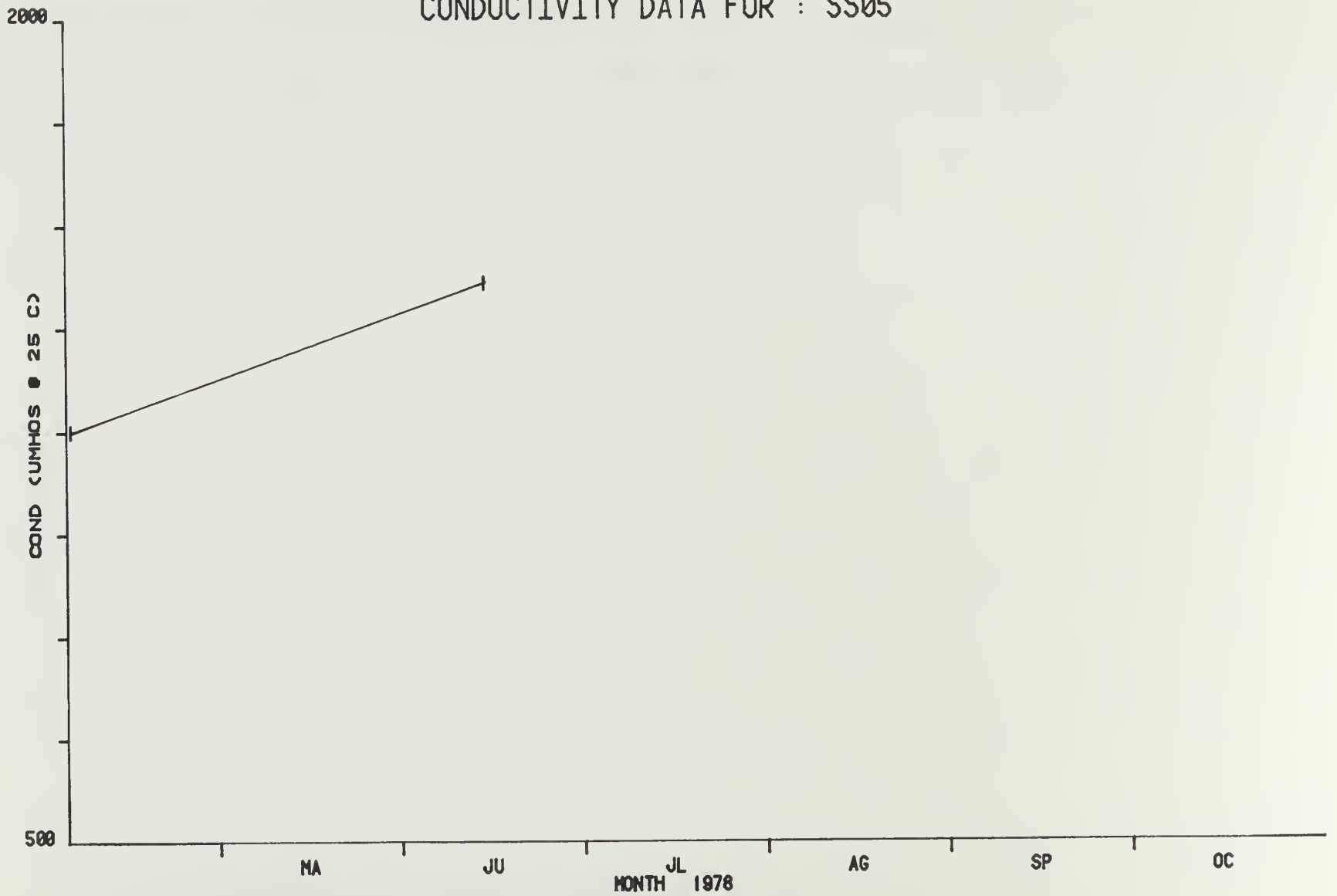

FIGURE 5-25. Conductivity Data for Spring No. 5 near Tract C-a, 1978

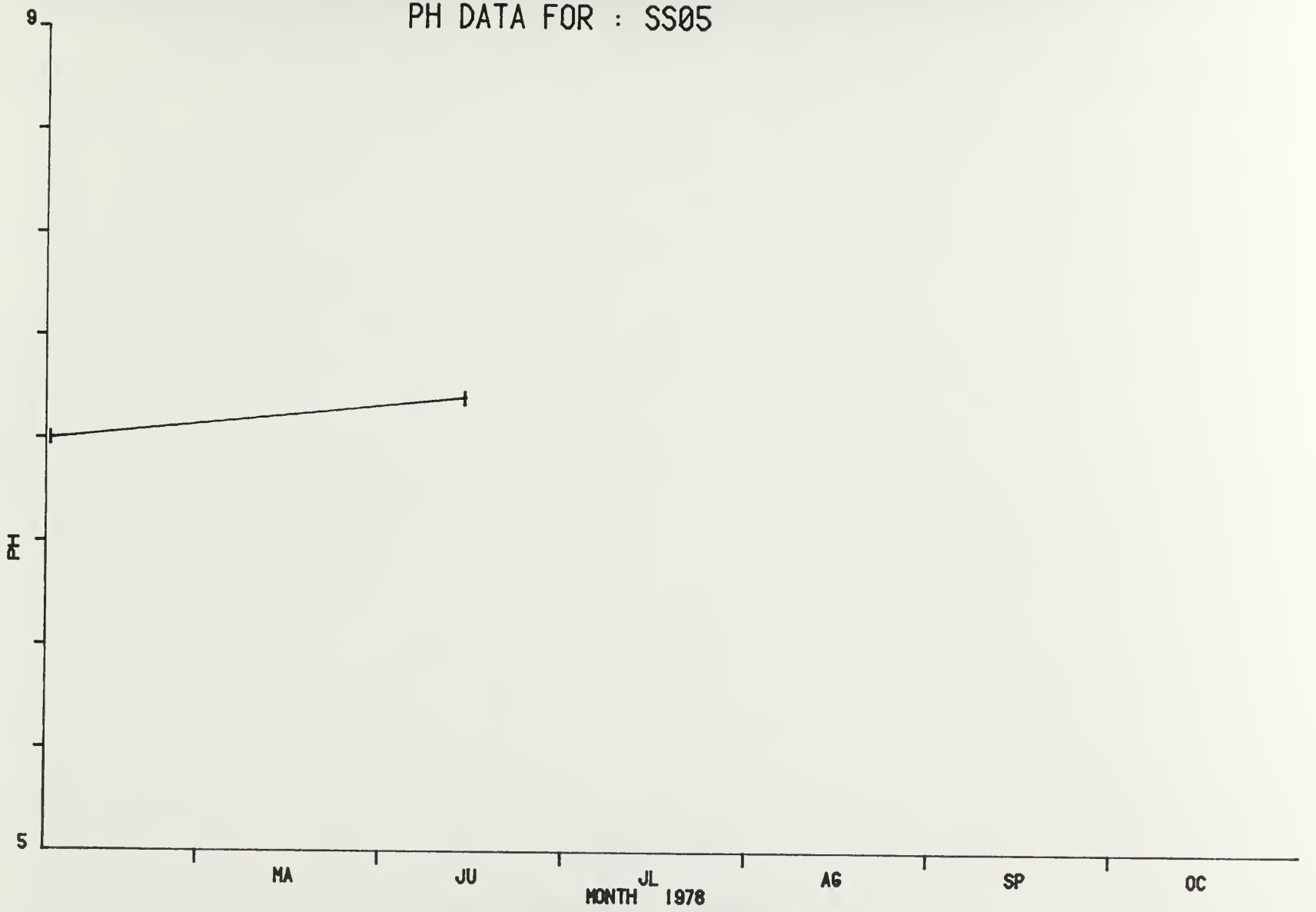

FIGURE 5-26. pH Data for Spring No. 5 near Tract C-a, 1978

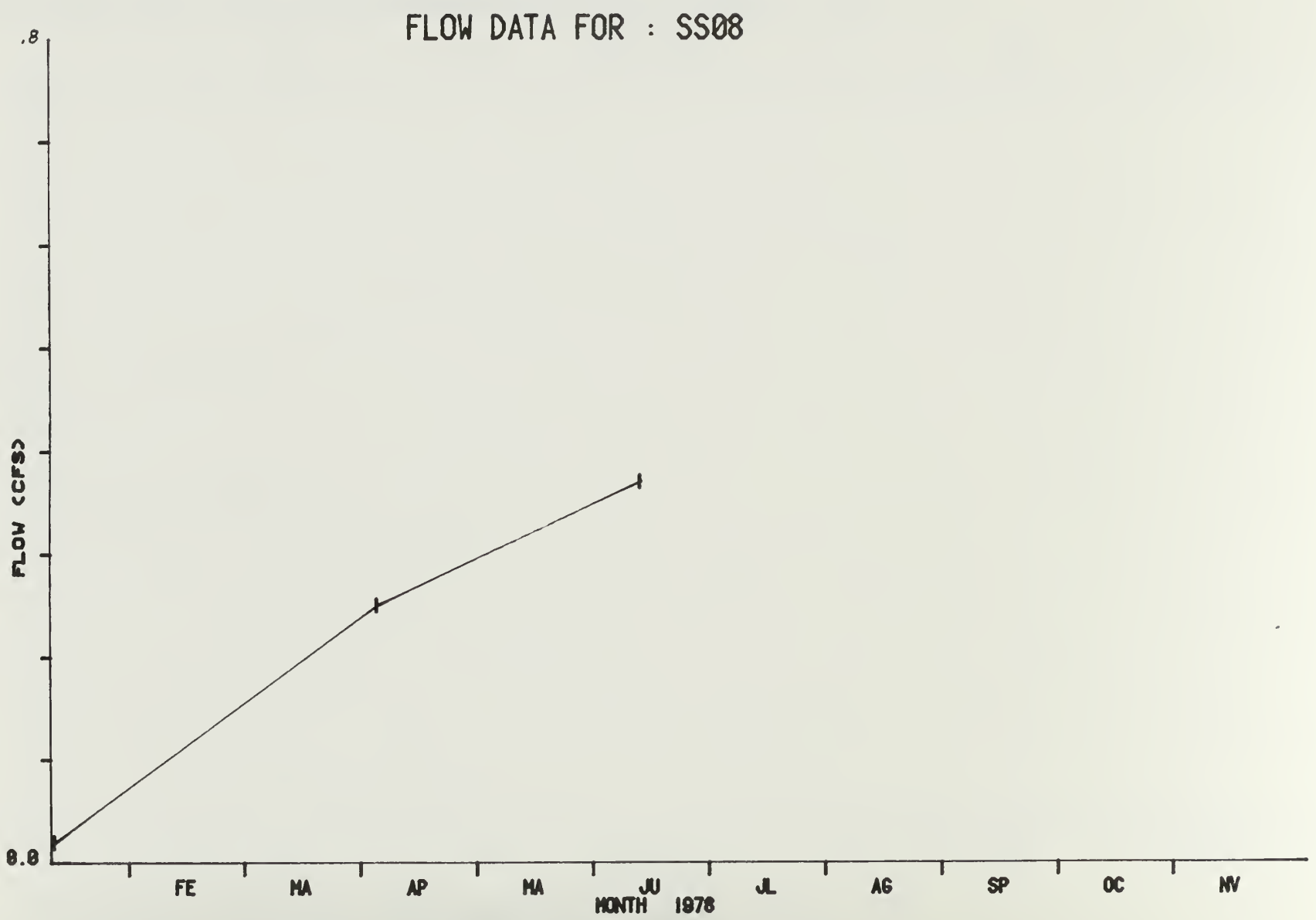

FIGURE 5-27. Flow Data for Spring No. 8 near Tract C-a, 1978

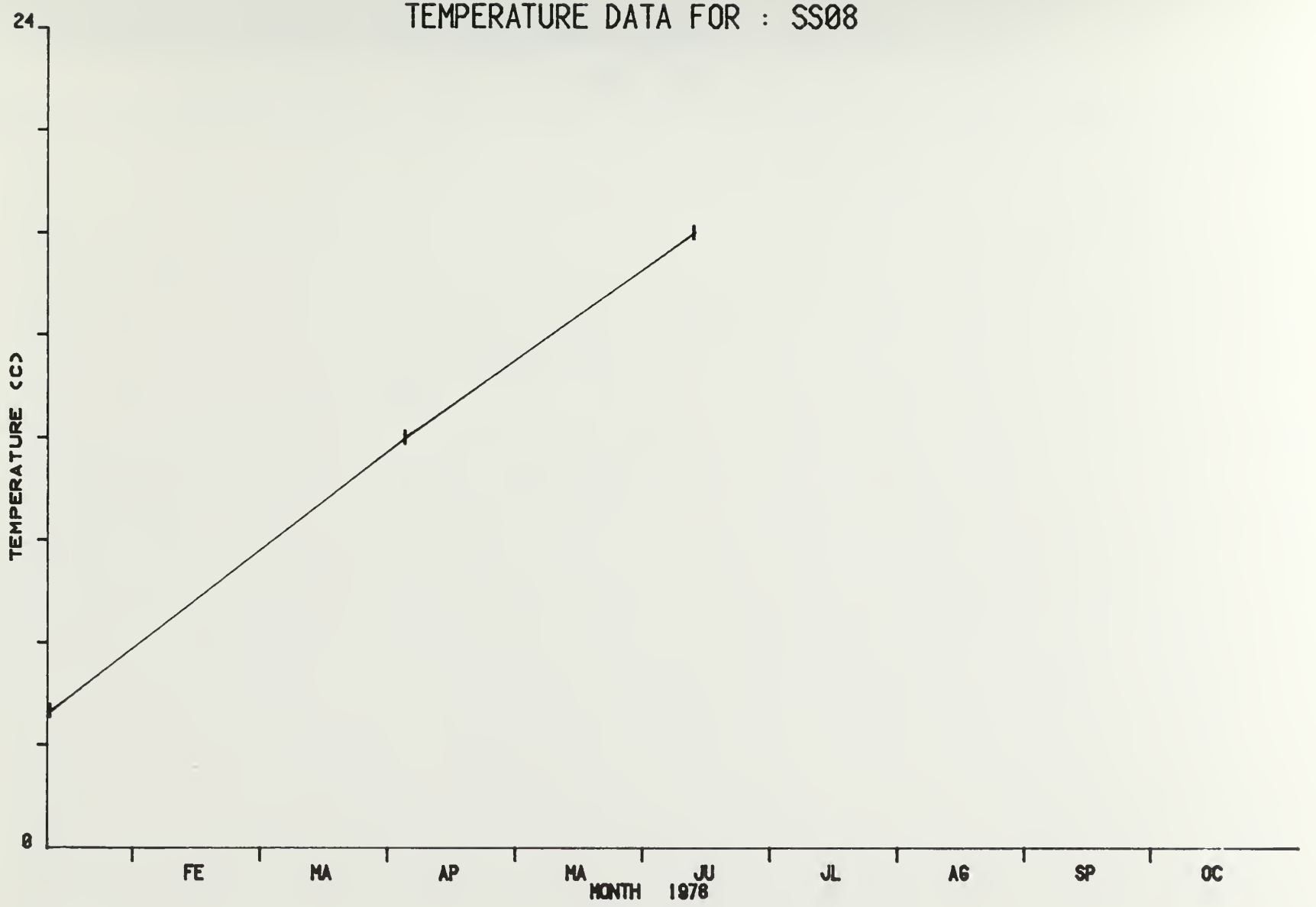

FIGURE 5-28. Temperature Data for Spring No. 8 near Tract C-a, 1978

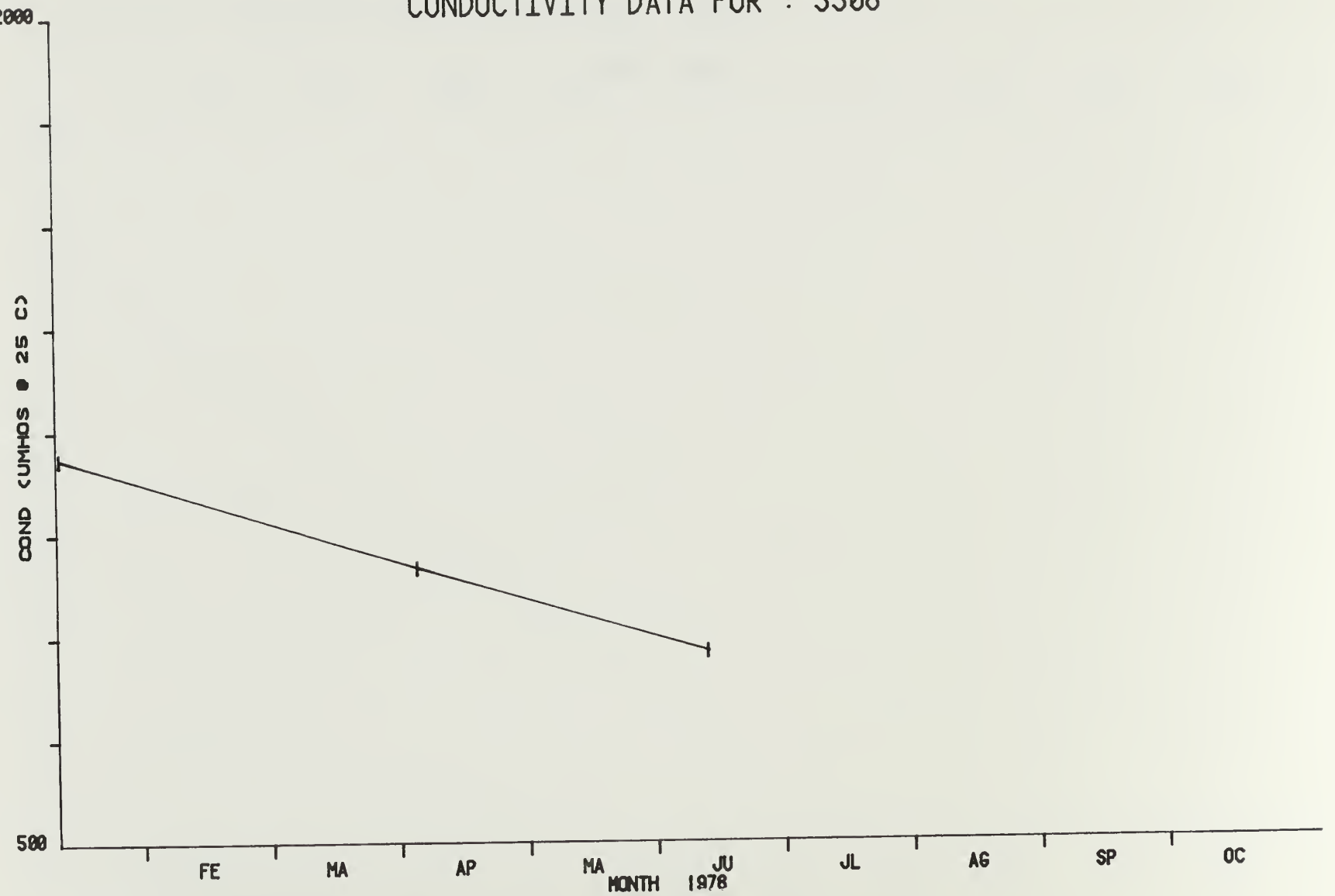

FIGURE 5-29. Conductivity Data for Spring No. 8 near Tract C-a, 1978

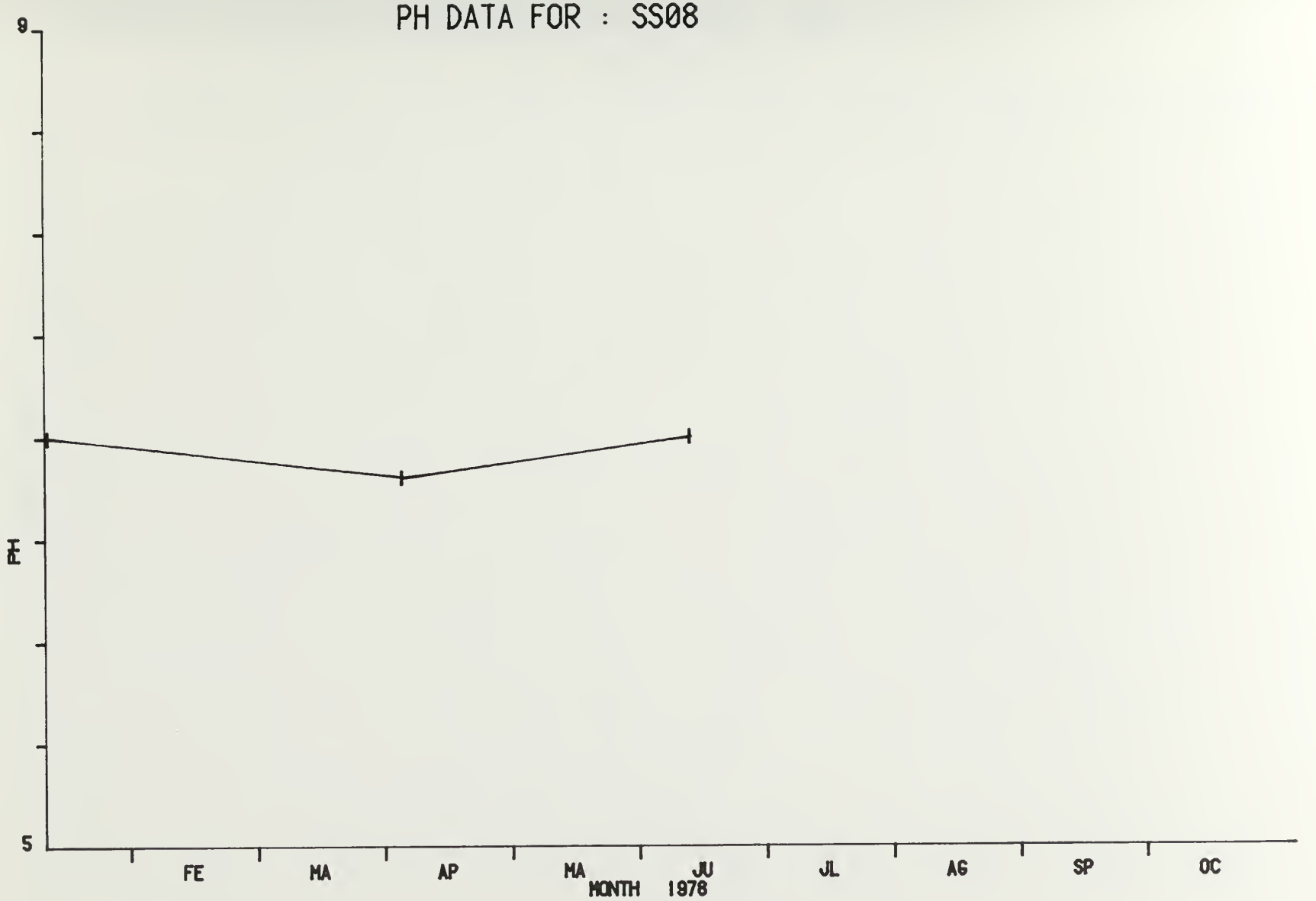

FIGURE 5-30. pH Data for Spring No. 8 near Tract C-a, 1978

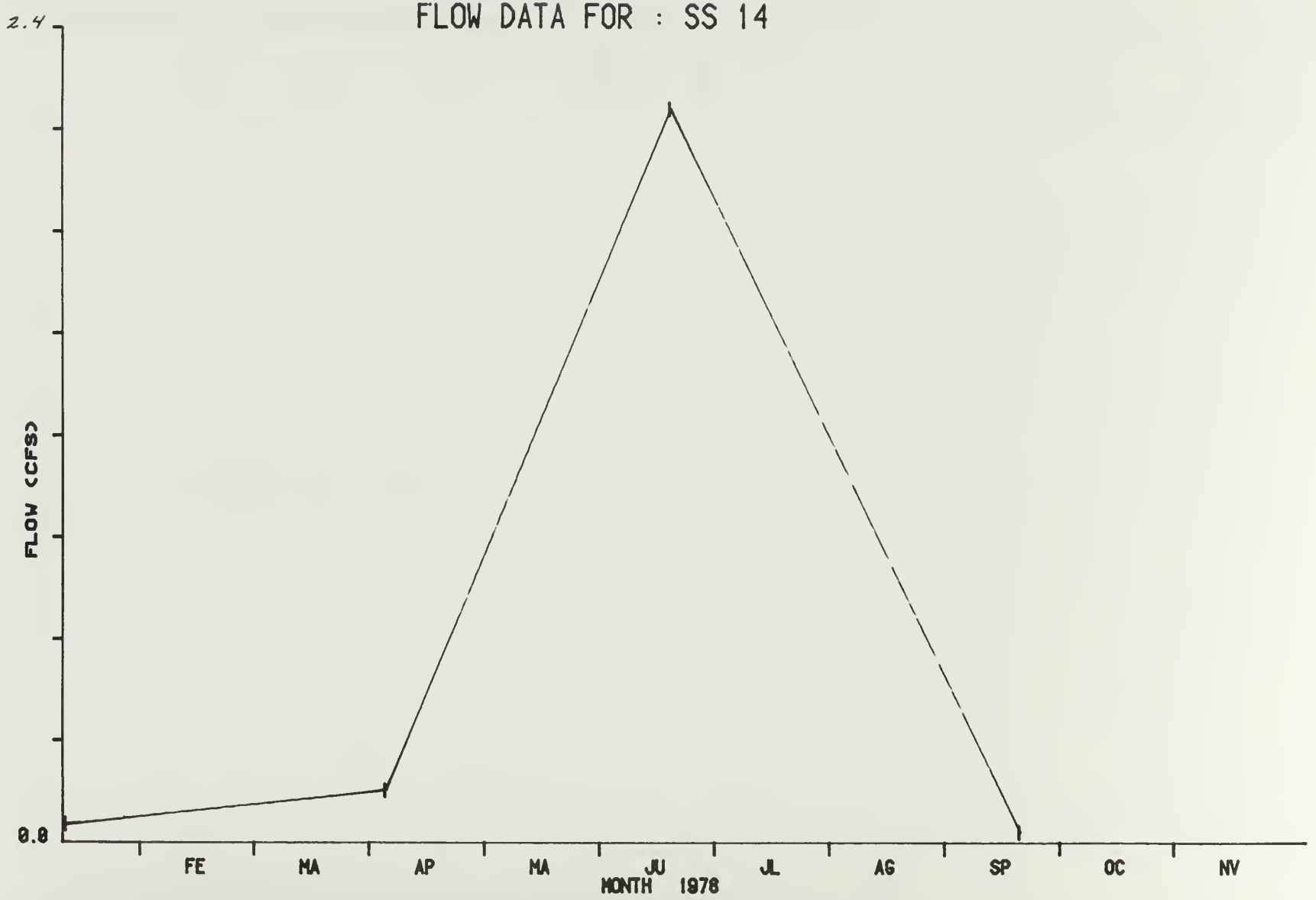

FIGURE 5-31. Flow Data for Spring No. 14, near Tract C-a, 1978

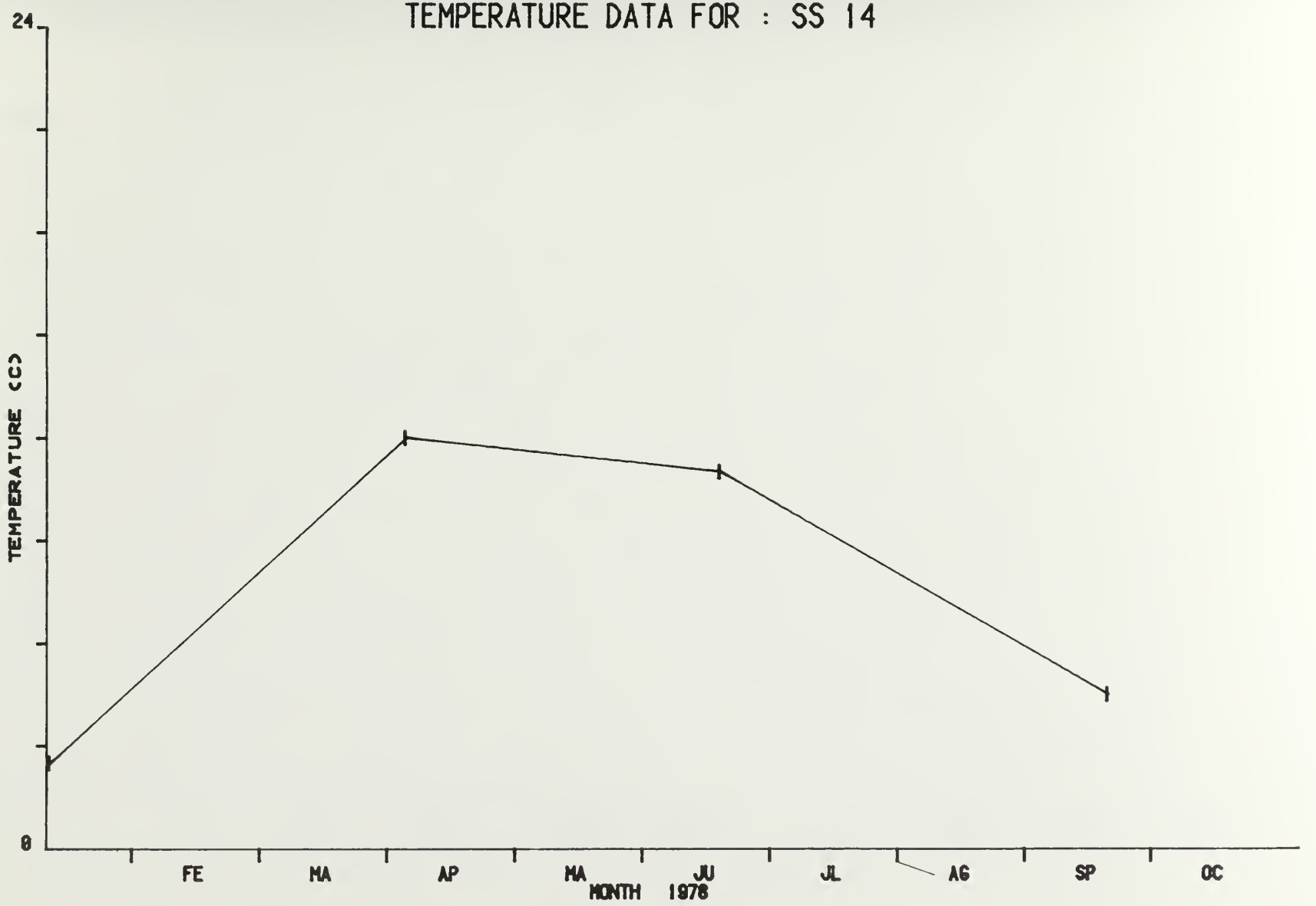

FIGURE 5-32. Temperature Data for Spring No. 14 near Tract C-a, 1978

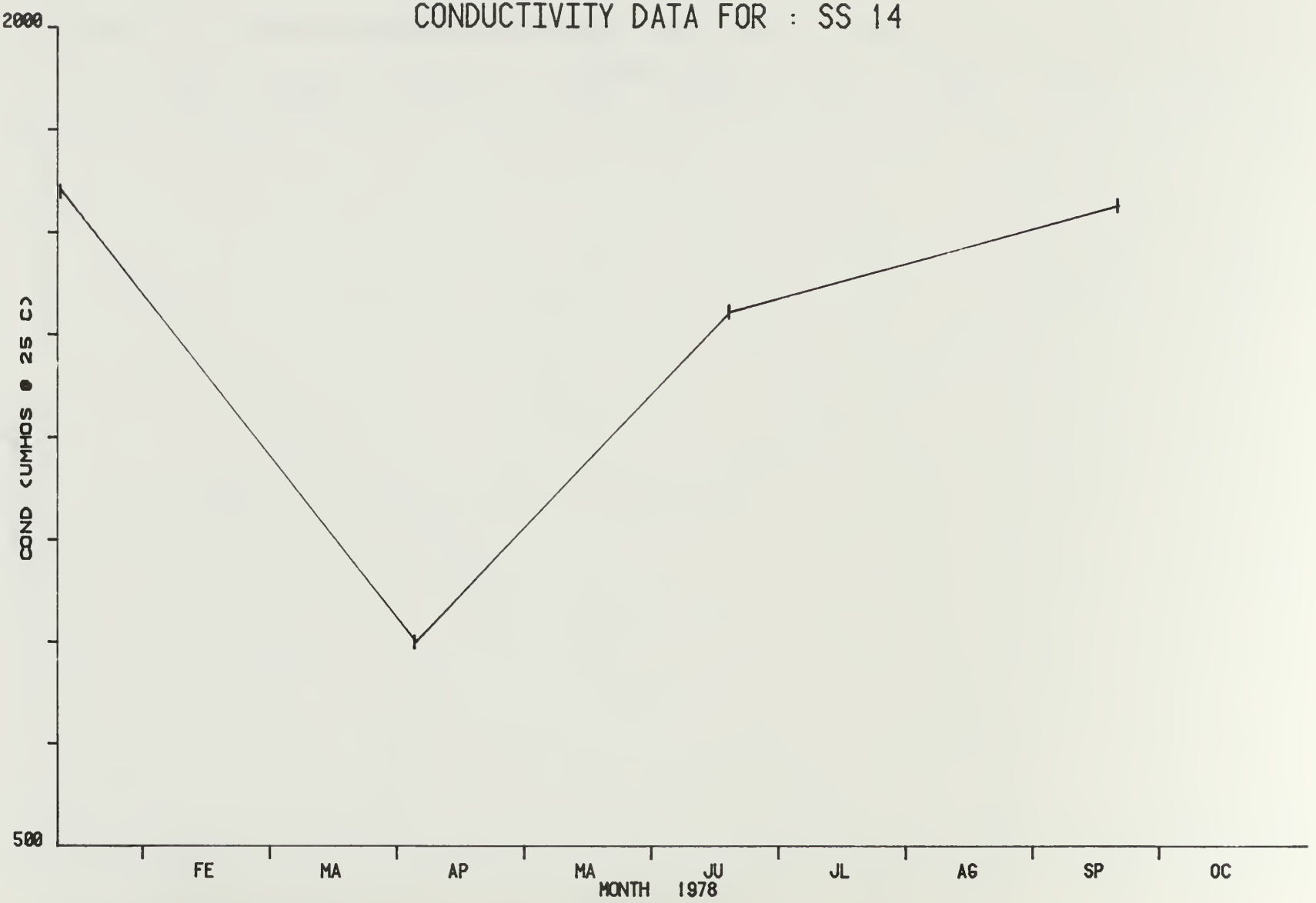

FIGURE 5-33. Conductivity Data for Spring No. 14 near Tract C-a, 1978

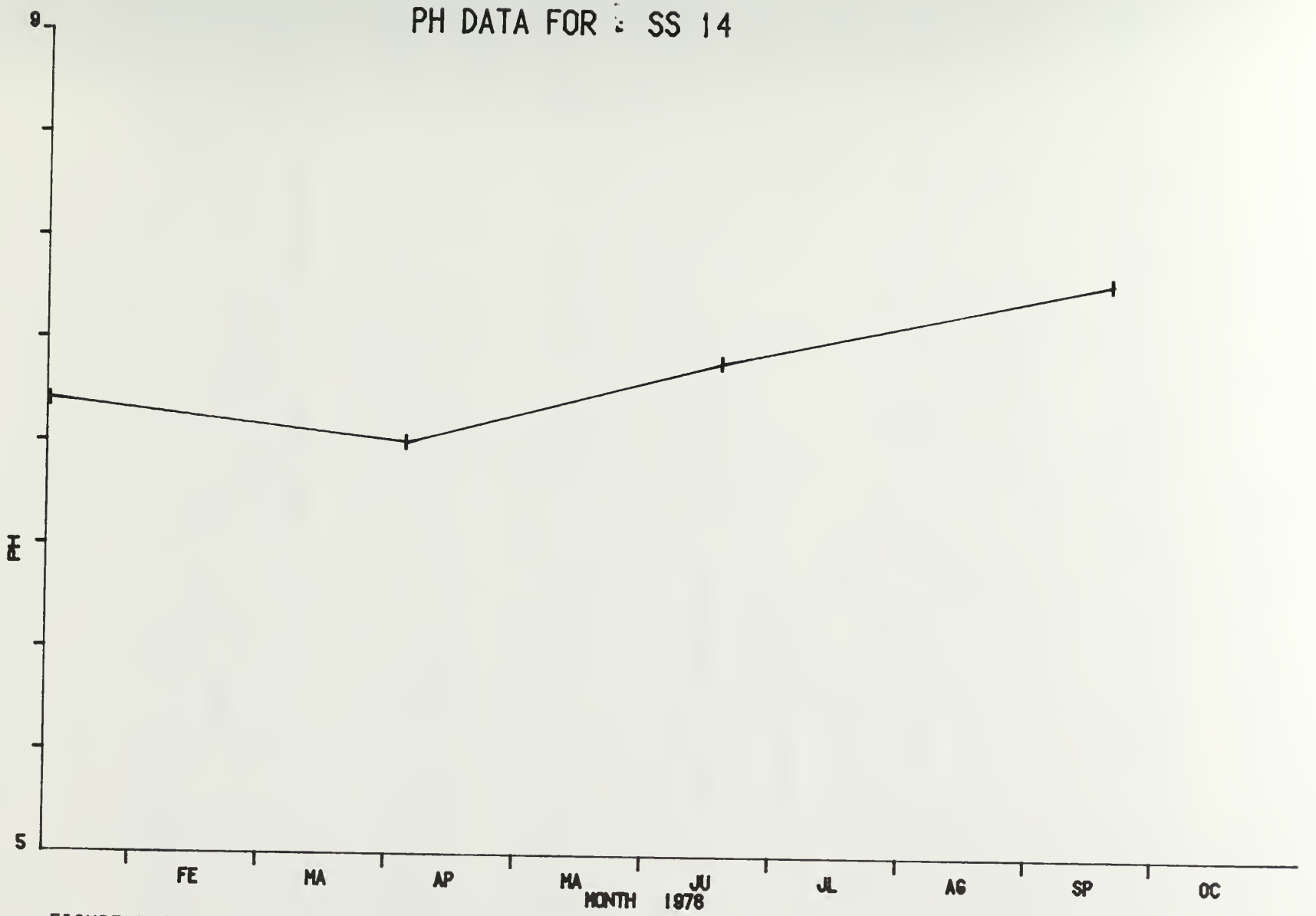

FIGURE 5-34. pH Data for Spring No. 14 near Tract C-a, 1978

An additional statistical test, the F Test, a method of Analysis of Variance (ANOVA), was used for the alluvial water quality data. MDP data were compared with baseline data to determine the equivalency of their variances.

The null hypothesis for the F test states that the apparent populations of the two groups have equal variances. $F = s_1^2 \div s_2^2$, where s_1^2 is the larger variance and s_2^2 is the smaller variance. Due to sampling fluctuations, some differences in variances might be noticed. In order to take into account these sampling fluctuations, a 95 percent confidence level has been used. The calculated results from the above formula are then compared to an F table. If the calculated value exceeds the value in the F table, then it may be said that the differences among the groups must be greater than that ascribed to sampling fluctuations and the groups are not from the same population, and, therefore, the null hypothesis is rejected.

3. Results and Discussion

a. Physical Parameters - During the baseline program, three of the original seven alluvial wells (G-S S6, G-S S13, and G-S S14) were dry. Of the additional new wells, G-S S25 and G-S S26 were found to be dry during this reporting period. Table 5-7 indicates the months during which data were taken and lists the wells included in the program. The physical data taken during the baseline are summarized in Table 5-8.

A list of alluvial wells samples as a part of the MDP program, the types of data collected, and the condition (Dry, or Containing water) of each well during the 1977-78 sampling period is shown on the following page.

The remaining monitor holes contained or did contain water at some time during the period. Figure 5-35 illustrates the method of completion of each hole and Table 5-9 indicates the depth of each hole to the perforated interval. Water level, temperature, conductivity and pH data for these holes are shown in Figures 5-36 through 5-51.

TABLE 5-7 ALLUVIAL WELL MONITORING SUMMARY

	1977			1978										
Well #	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
G-S S6	D			D		D	D	D	D	D	D	D	D	D
G-S S7	X	X		C	X	C	X	X	C		C	C	C	
	B			L			L		B			X		
G-S S8	X			X			X					X		D
	B								B			L		
G-S S11	X		C	C	C	C	C	C	C	C	C	C	C	C
	B			L		L	L		B			L	B	
G-S S13	D			D		D	D	D	D	D	D	D	D	D
G-S S14	D			D		D	D	D	D	D	D	D	D	D
G-S S24	X					C	C	C	C	C	C	C	C	C
	B					L	L		B			L	B	
G-S S26		X		C	D	D	D	D	D	D	D	D	D	D
	B			L										
G-S S27		X		C	C	C	C	C	C	C	C	C	C	C
	B	B		L		L	L		B			B	B	
G-S S27A						D	D	C	C	X	D	D	D	D

X = Water level taken during the month

L = Limited Water quality sample taken

B = Complete (baseline suite) water quality sample taken

D = Dry

C = Water level, conductivity, temperature, pH taken during the month

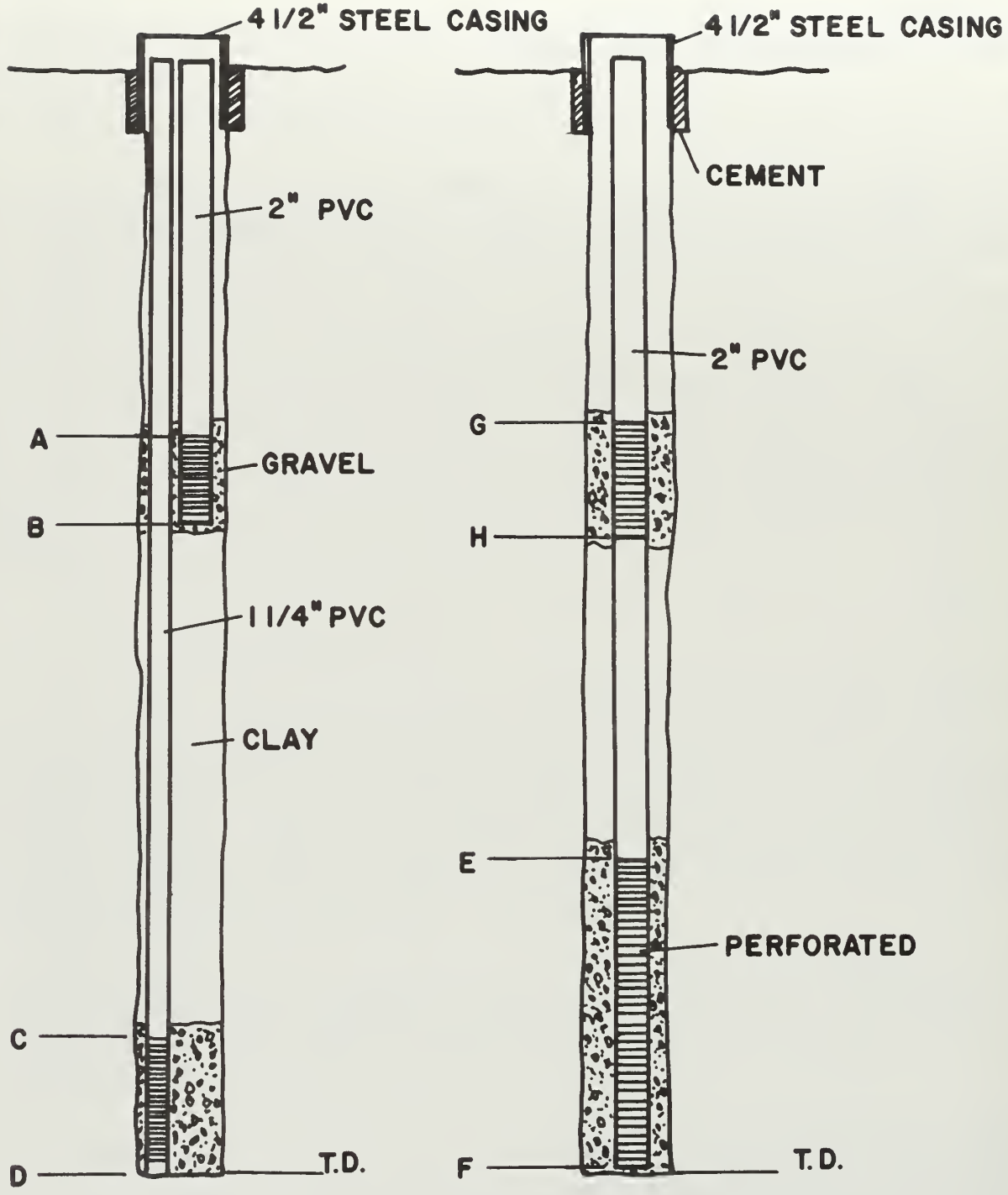

Figure 5-35 Diagramatic (Section) Alluvial Monitoring Hole

The physical data collected for G-S S7 and G-S S8, which include water level, temperature, conductivity, and pH, do not appear to have varied greatly from the data collected during the baseline period. This was expected since these two monitoring holes are upgradient from any Tract C-a activities.

TABLE 5-8 SUMMARY OF BASELINE DATA FROM ALLUVIAL MONITORING HOLES 1974-76, TRACT C-a

Hole	Depth (feet)	Mean Static Water Level (feet)	Stand. Dev.	Mean Temp. (°C)	Stand. Dev.	Mean* Cond. (umhos)	Stand.* Dev.
G-S S7	44	21.6	2.5	9.22	2.9	1096	58.0
G-S S8	50	35.7	3.7	9.56	2.9	970	83.3
G-S S11	66	44.0	1.5	10.33	3.0	1796	187.5

* Geometric mean, standard deviation by method of movements.

The depth of the water level in G-S S11 in February 1978 was approximately the same as the maximum depth encountered during the baseline period. However, in early May, the water levels begin rising and rose to about the minimum depth encountered during the baseline period. They have remained near this level. This rise in the water level corresponded to the increased discharge from the dewatering program. However, the water levels did not show a corresponding decline when the dewatering discharges were decreased. This lack of decline is, in all probability the result of the aquifer's having relatively low permeability, and, therefore, an associated lag-time for any major responses.

The conductivity data for G-S S11 from the period of January through May 1978 were similar to baseline data. Since May, conductivity has averaged about 1,380 micromhos per centimeter. This is approximately 70 micromhos per centimeter higher than the baseline mean but still within the range of values established during the baseline.

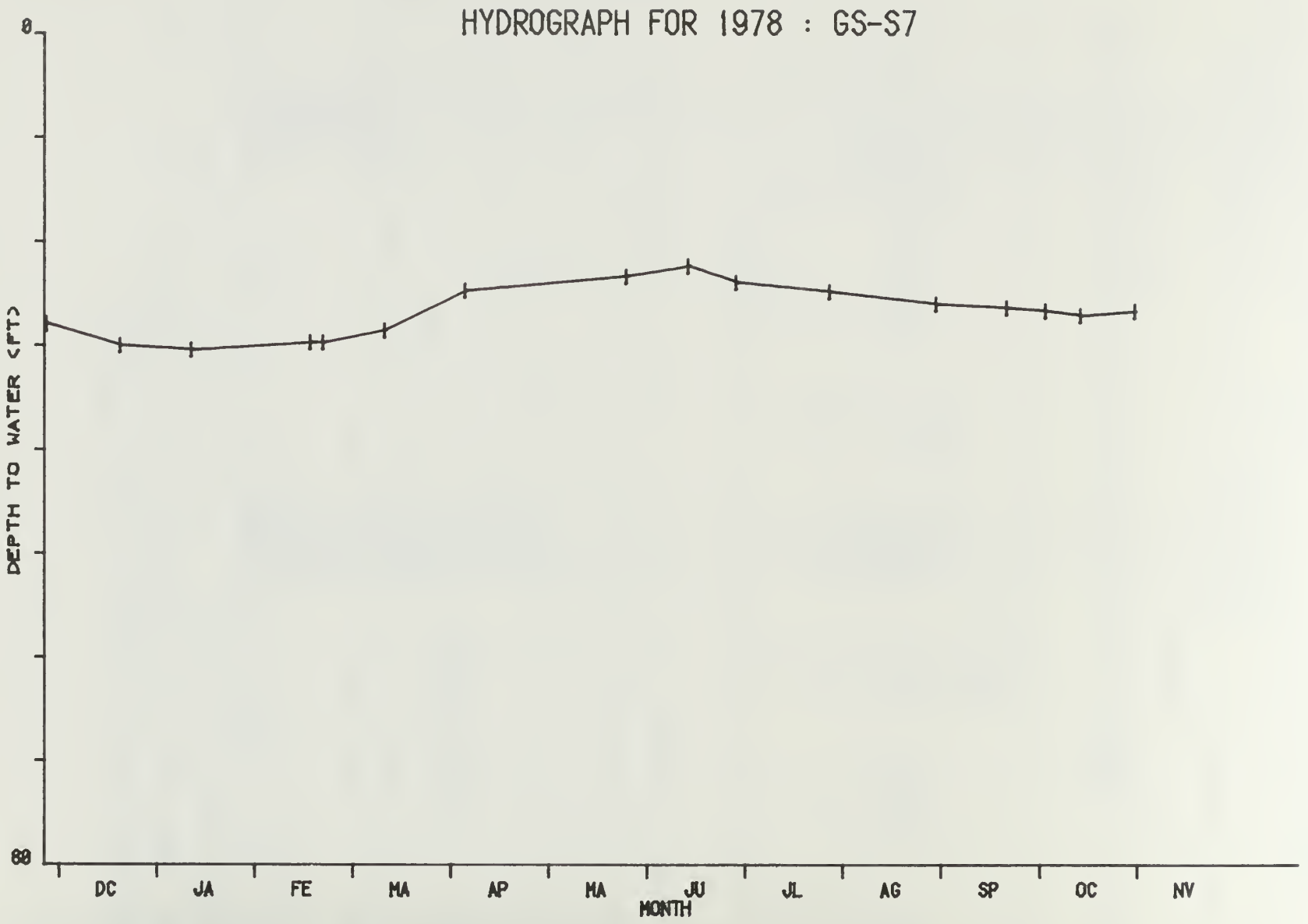

FIGURE 5-36 Water Level Hydrograph for Alluvial Hole G-S S7 for 1978, Tract C-a

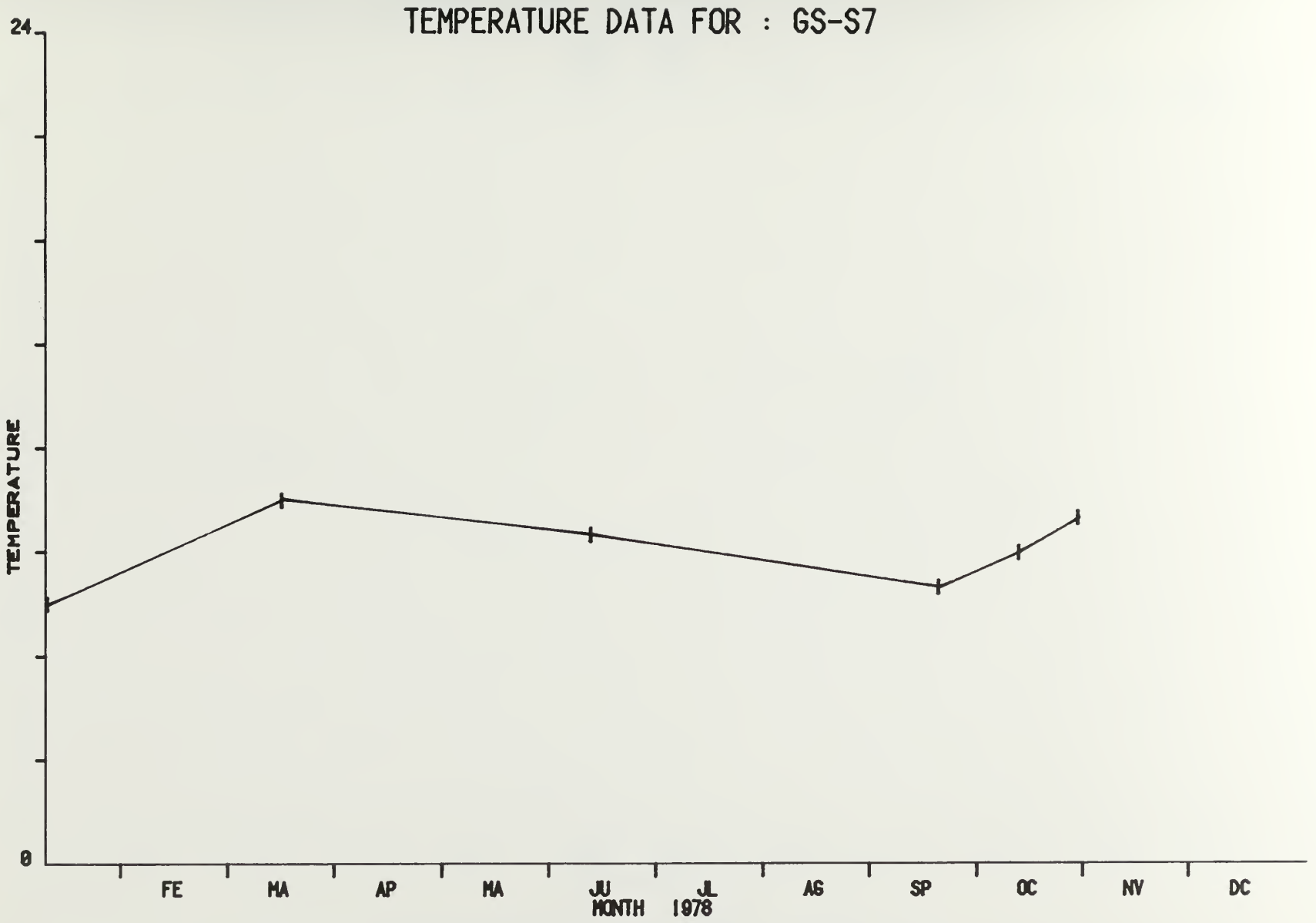

FIGURE 5-37 Temperature Data for Alluvial Hole G-S S7 for 1978, Tract C-a

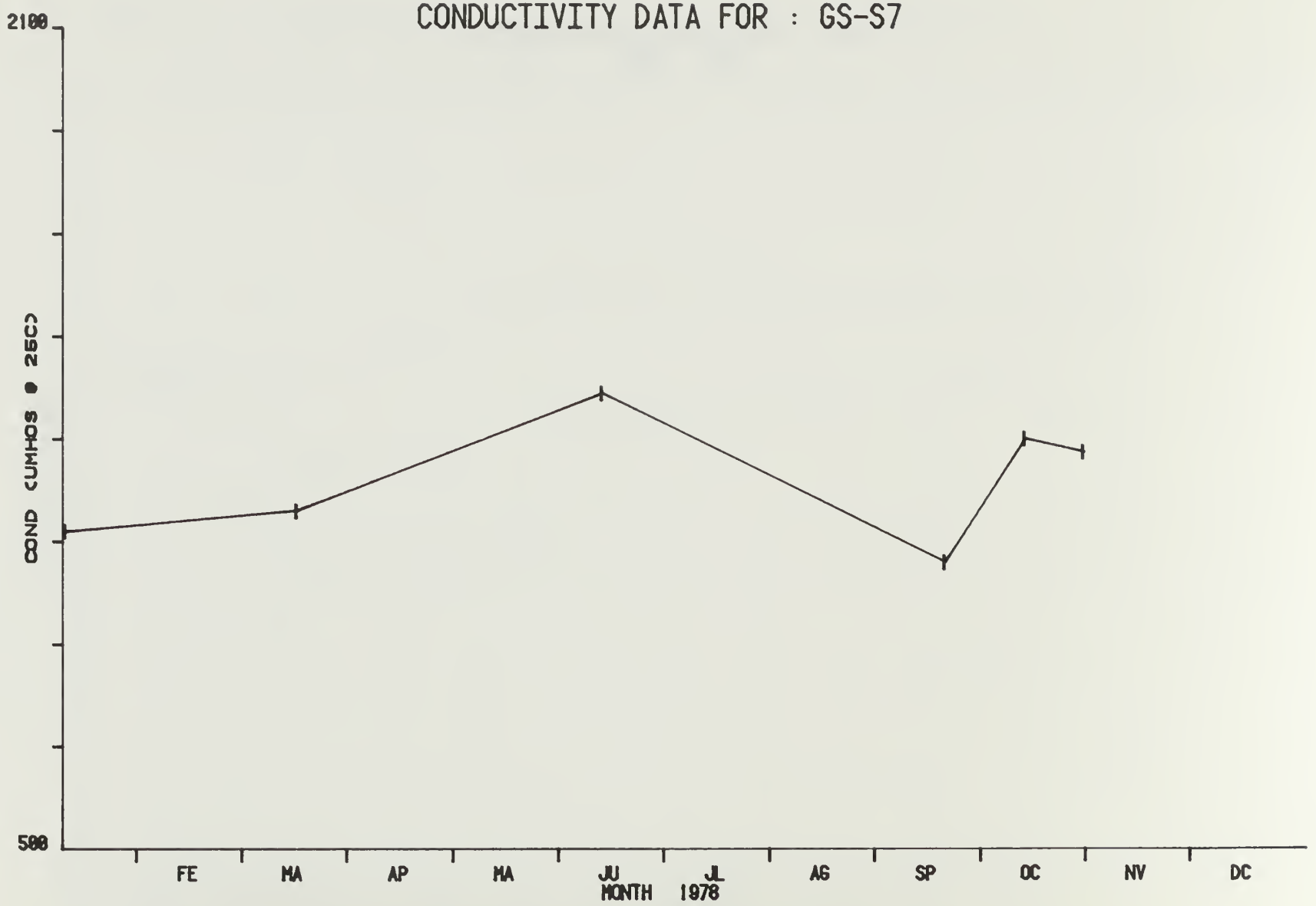

FIGURE 5-38 Conductivity Data for Alluvial Hole No. G-S S7 for 1978, Tract C-a

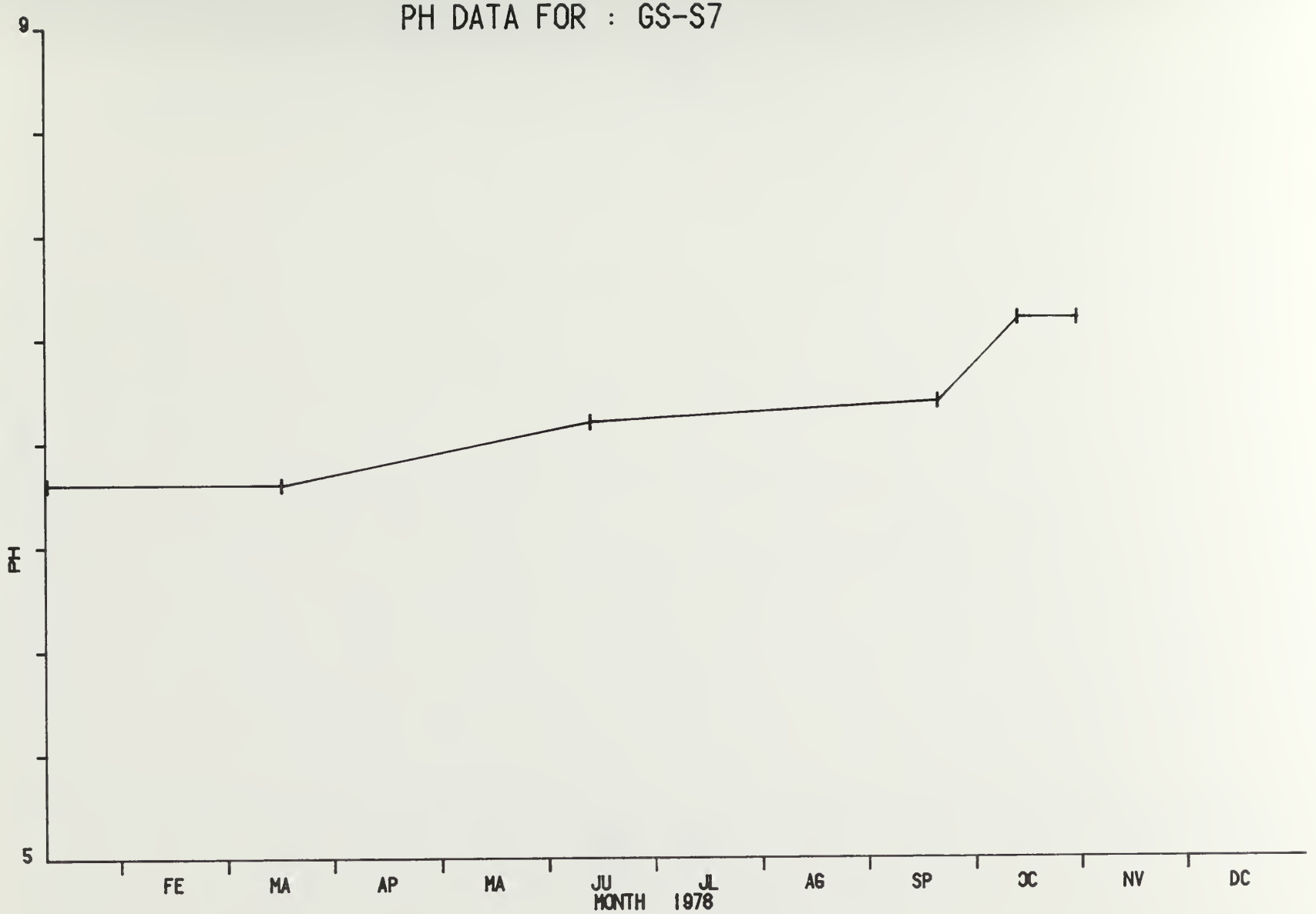

FIGURE 5-39 PH Data for Alluvial Hole G-S S7 for 1978, Tract C-a

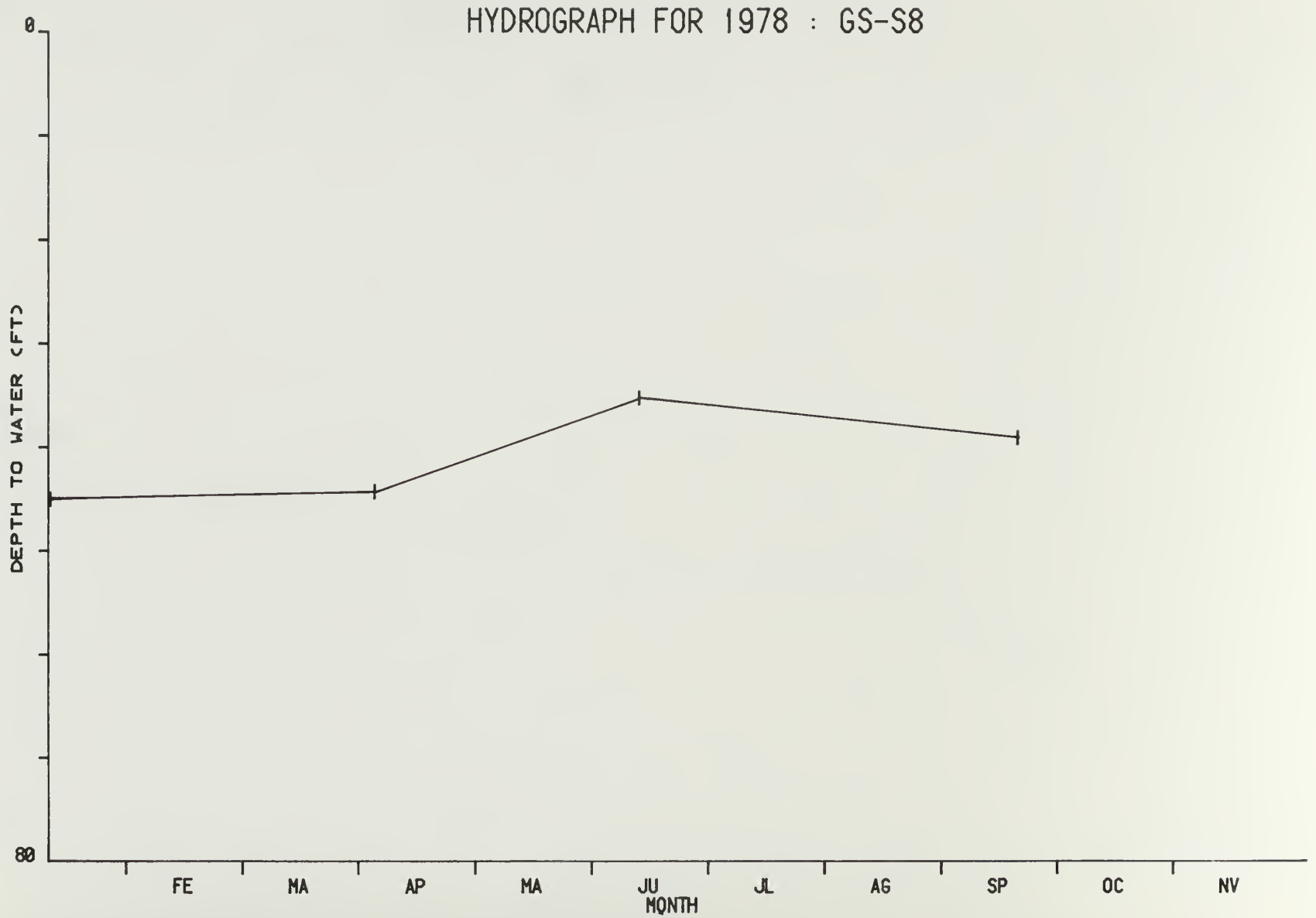

FIGURE 5-40 Water Level Hydrograph for Alluvial Hole G-S S8 for 1978, Tract C-a

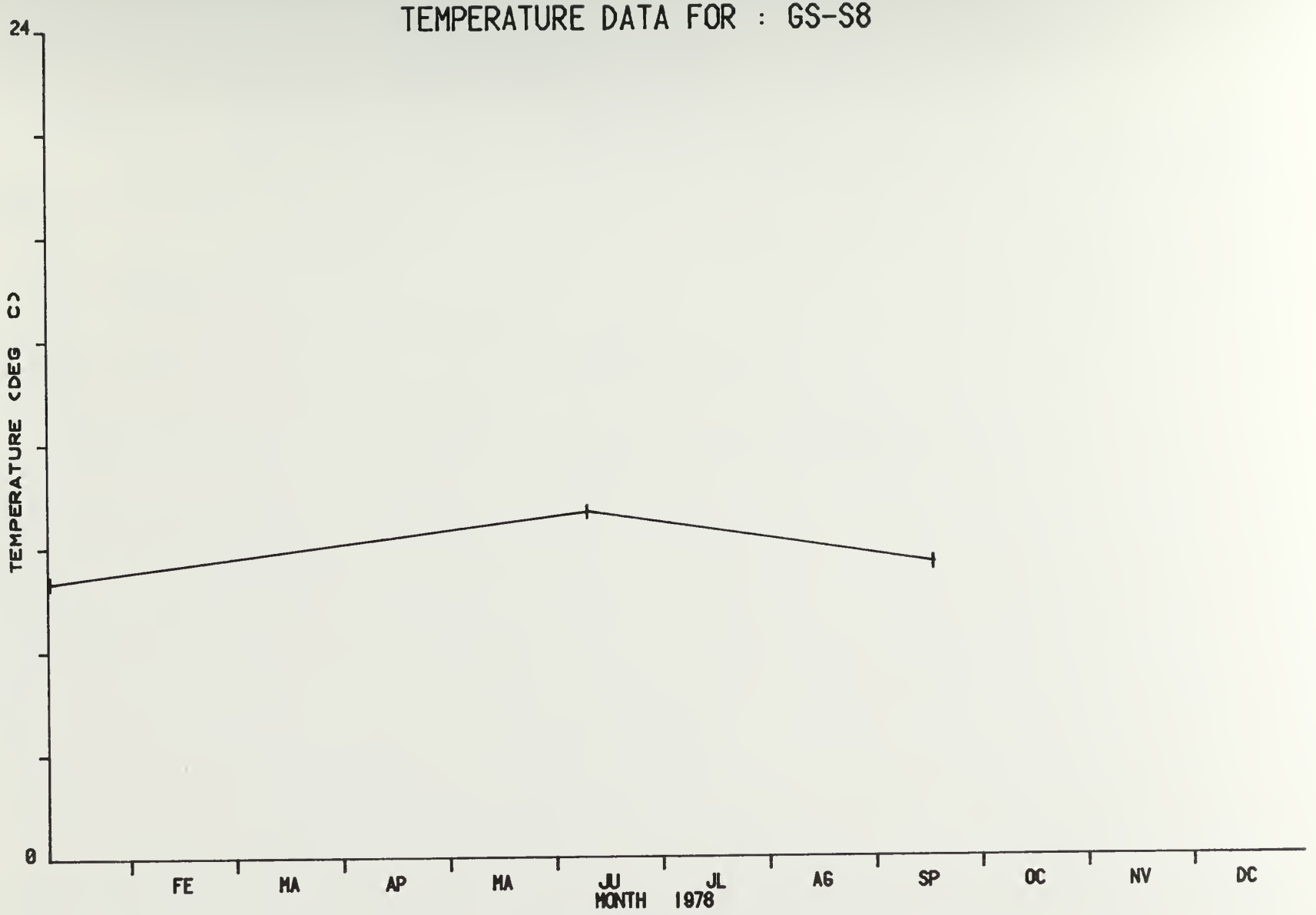

FIGURE 5-41 Temperature Data for Alluvial Hole G-S S8 for 1978, Tract C-a

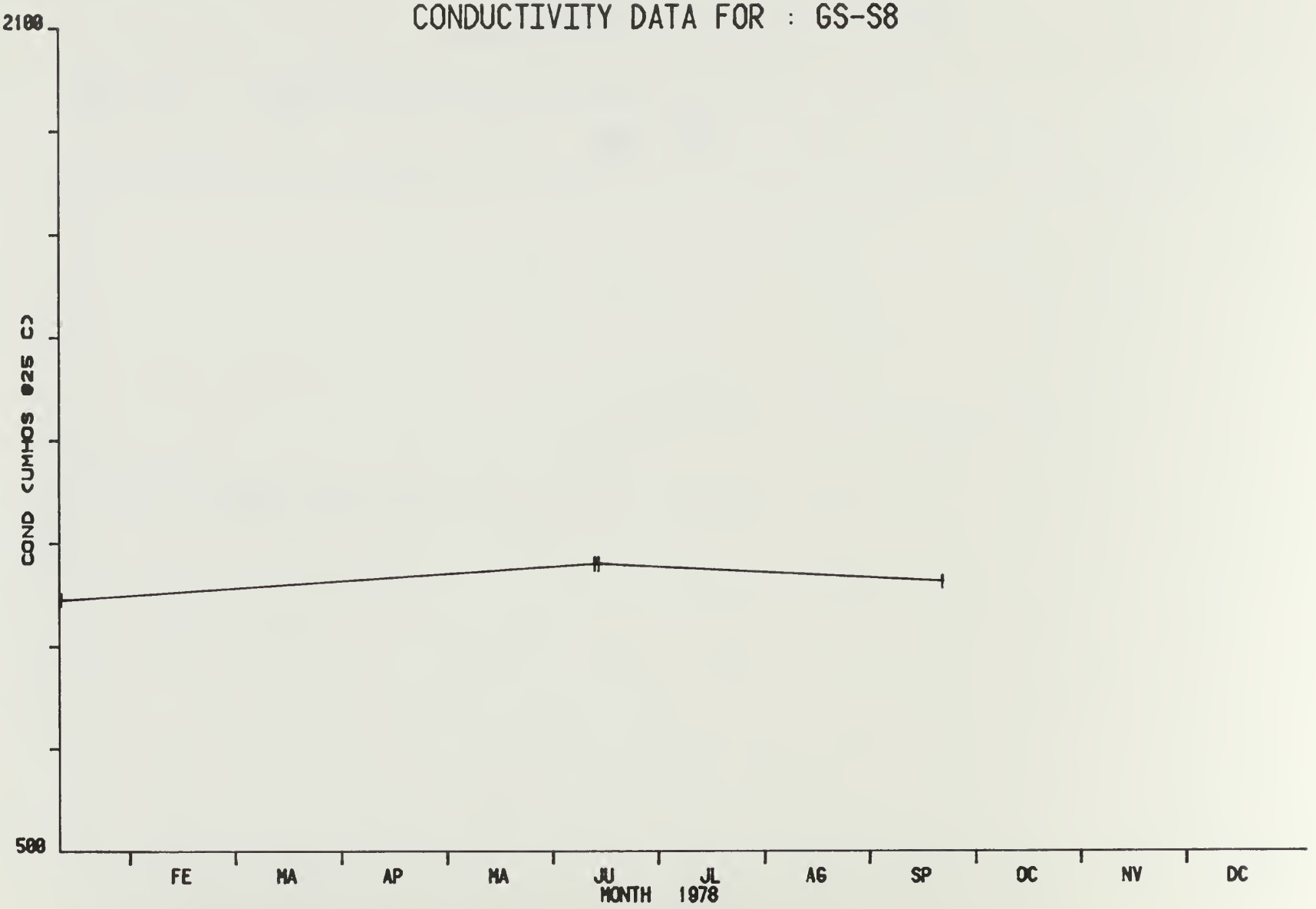

FIGURE 5-42 Conductivity Data for Alluvial Hole G-S S8 for 1978, Tract C-a

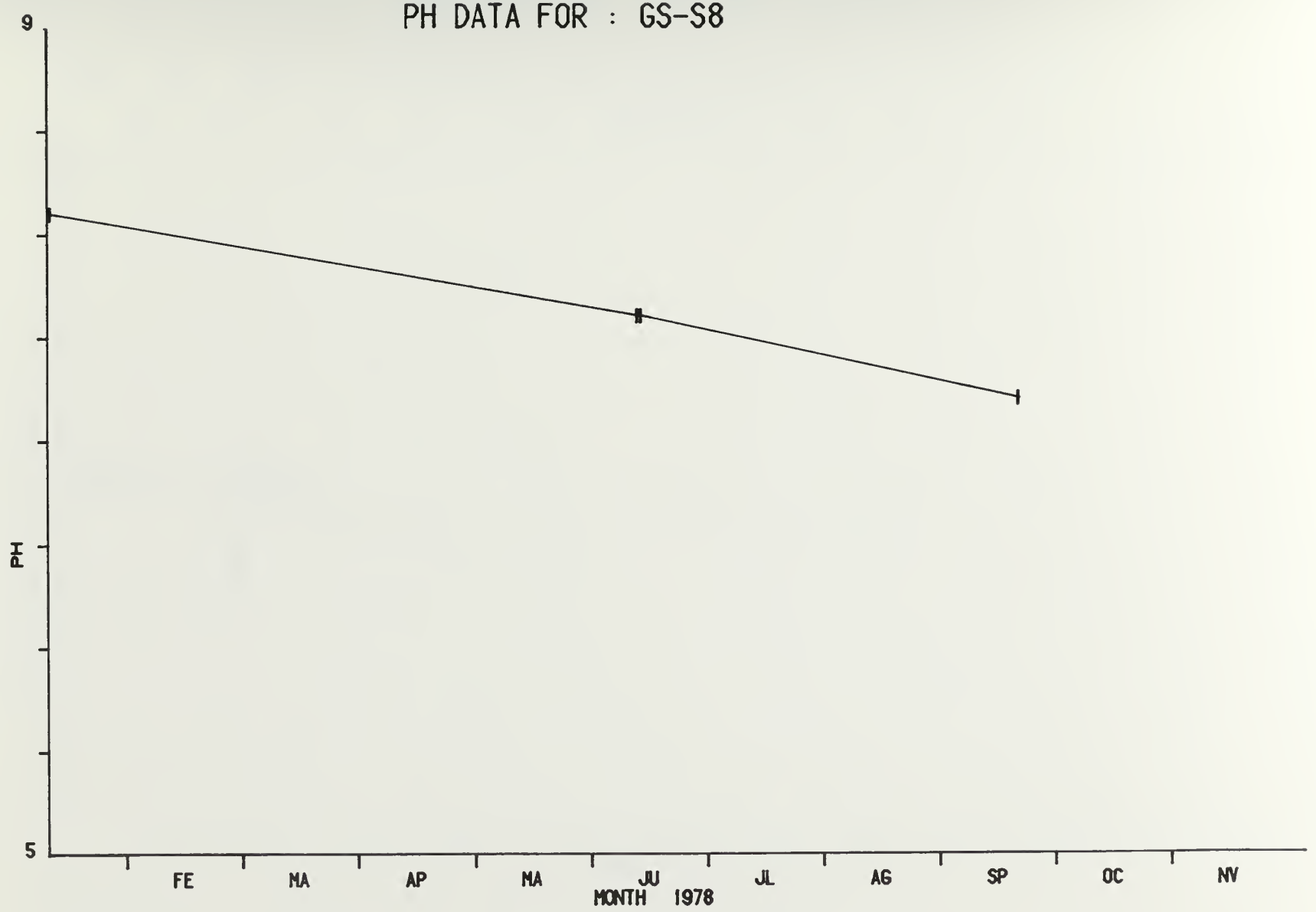

FIGURE 5-43 PH Data for Alluvial Hole G-S S8 for 1978, Tract C-a

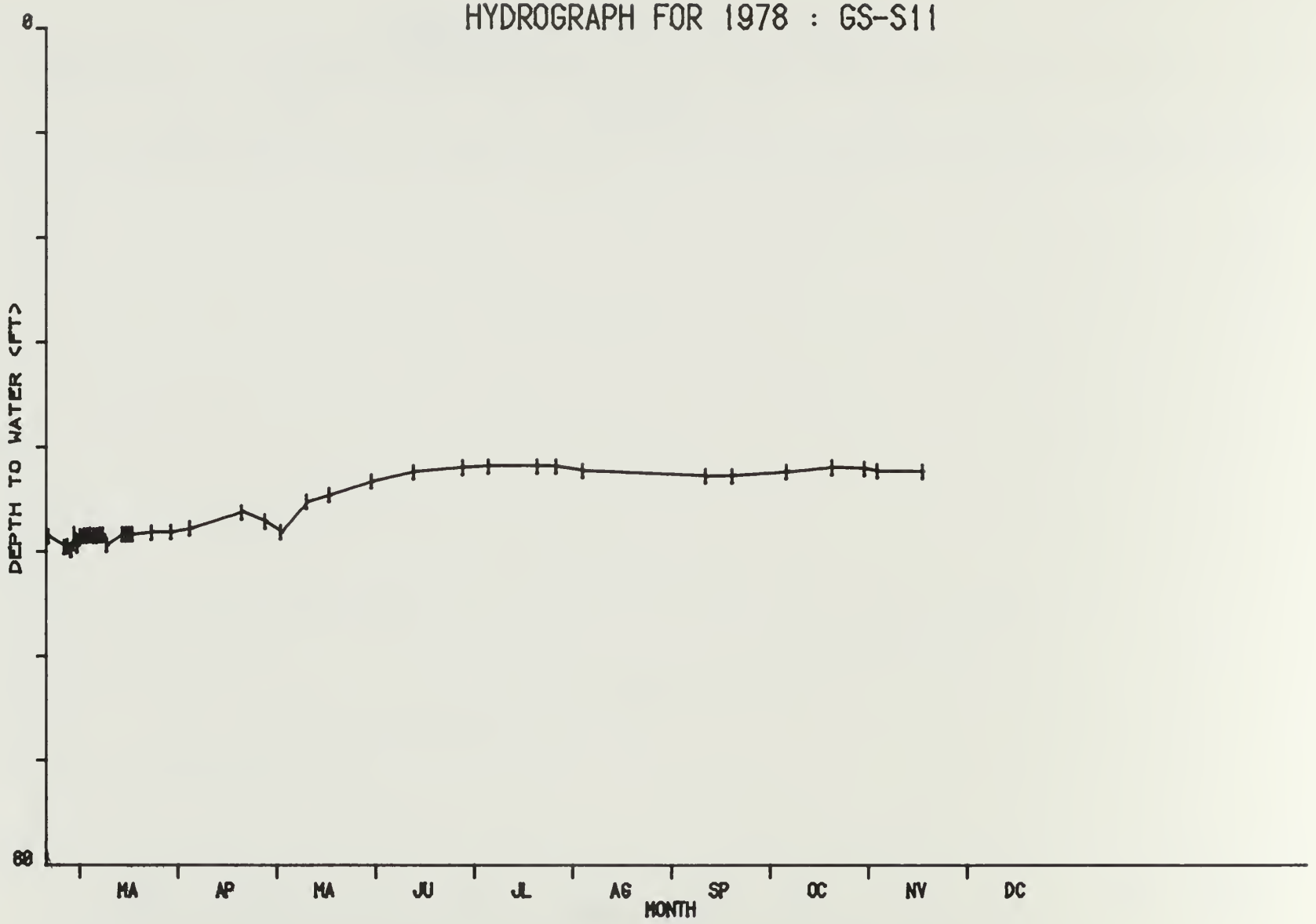

FIGURE 5-44 Water Level Hydrograph for Alluvial Hole G-S S11 for 1978, Tract C-a

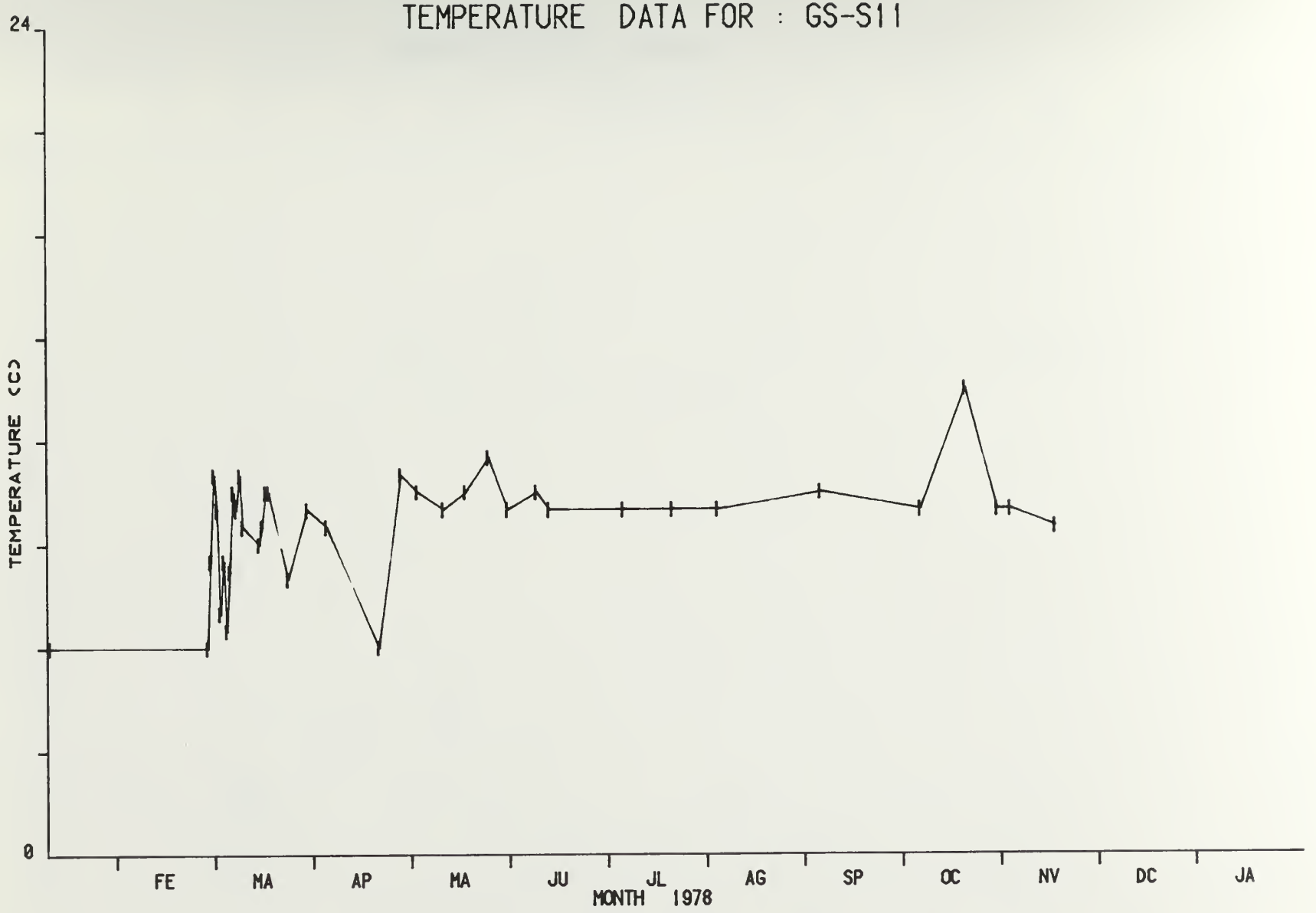

FIGURE 5-45 Temperature Data for Alluvial Hole No. G-S S11 for 1978, Tract C-a

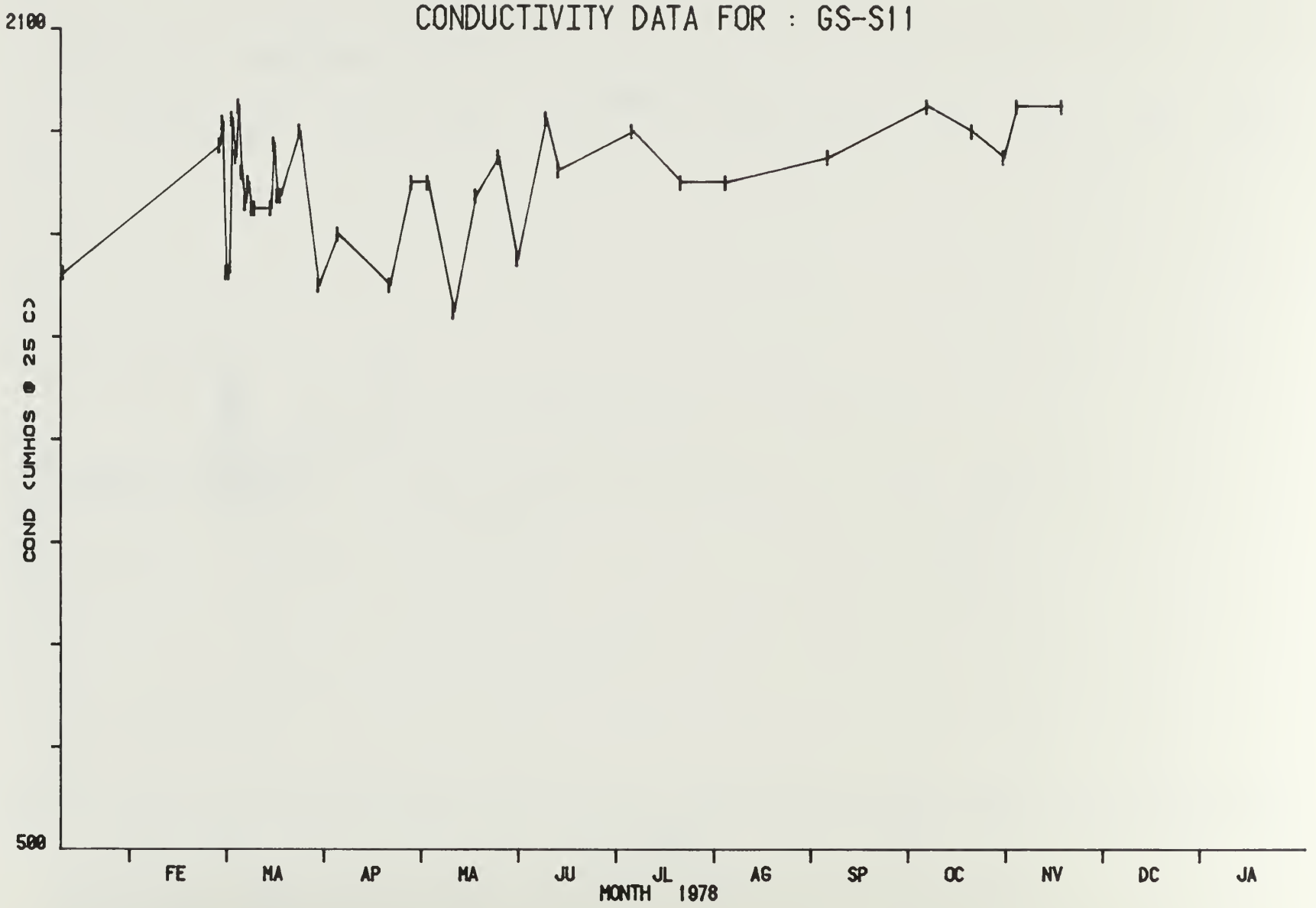

FIGURE 5-46 Conductivity Data for Alluvial Hole No. G-S S11 for 1978, Tract C-a

FIGURE 5-47 PH Data for Alluvial Hole No. G-S S11 for 1978, Tract C-a

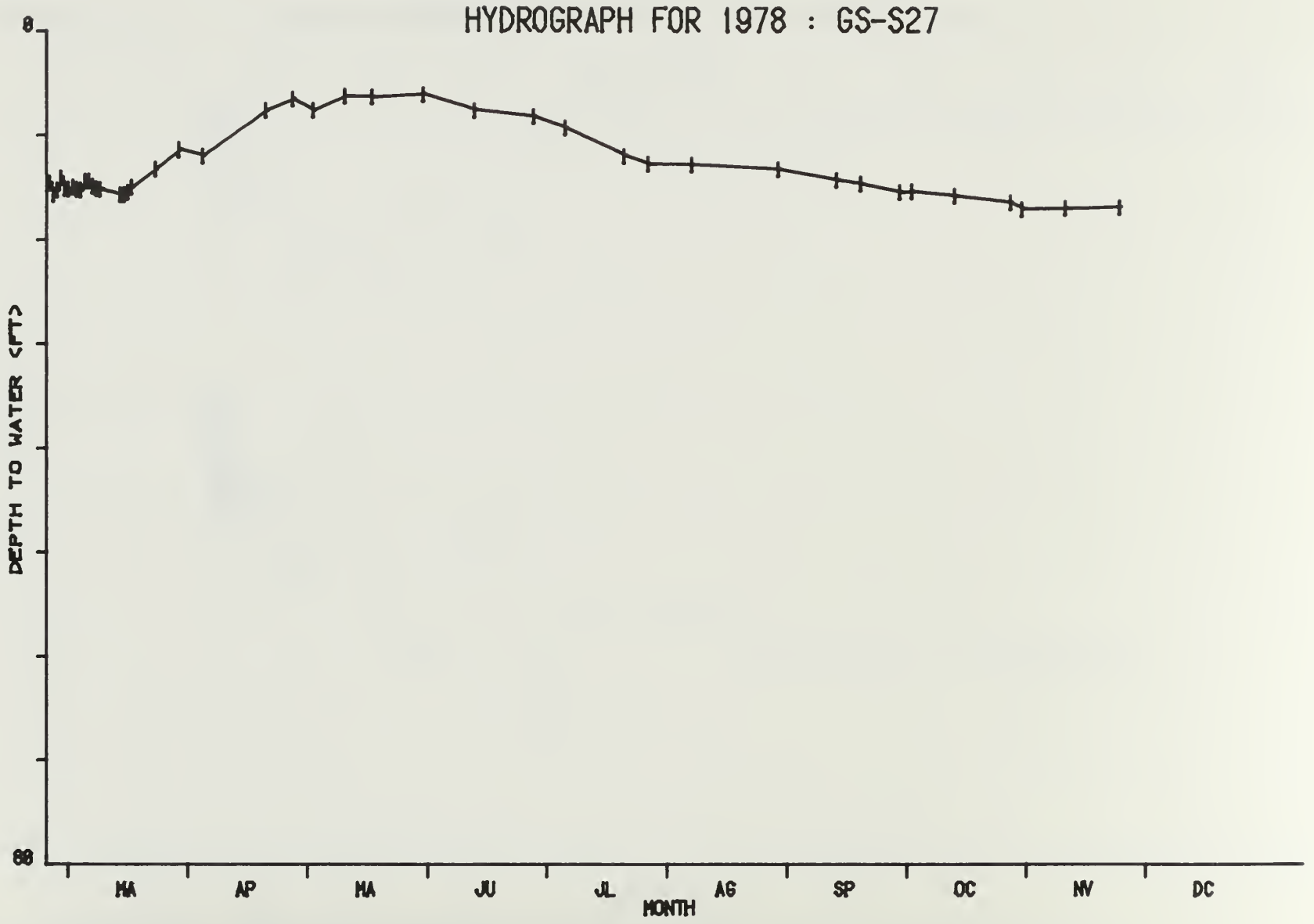

FIGURE 5-48 Water Level Hydrograph for Alluvial Hole No. G-S S27 for 1978, Tract C-a

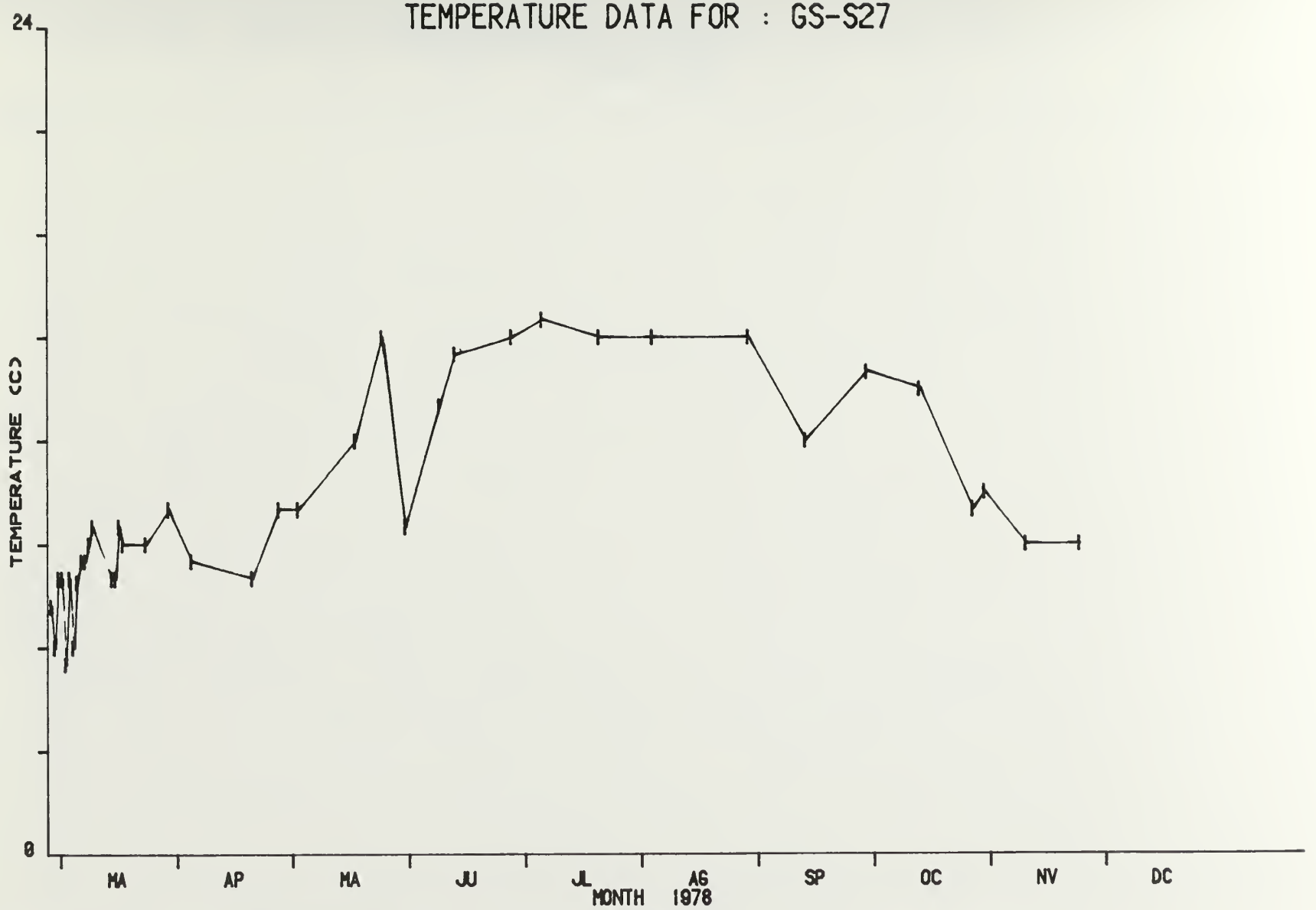

FIGURE 5-49 Temperature Data for Alluvial Hole No. G-S S27 for 1978, Tract C-a

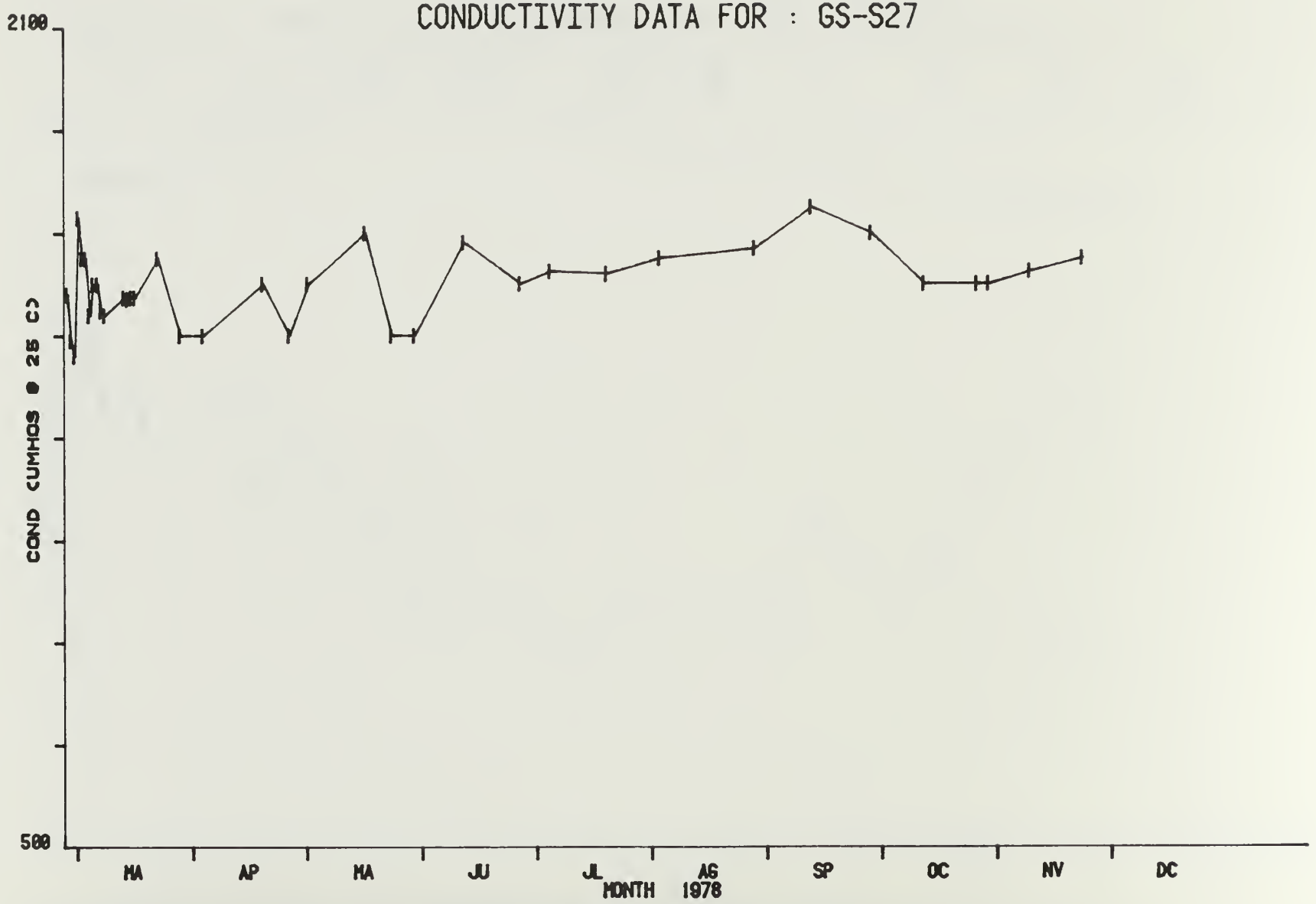

FIGURE 5-50 Conductivity Data for Alluvial Hole No. G-S S27 for 1978, Tract C-a

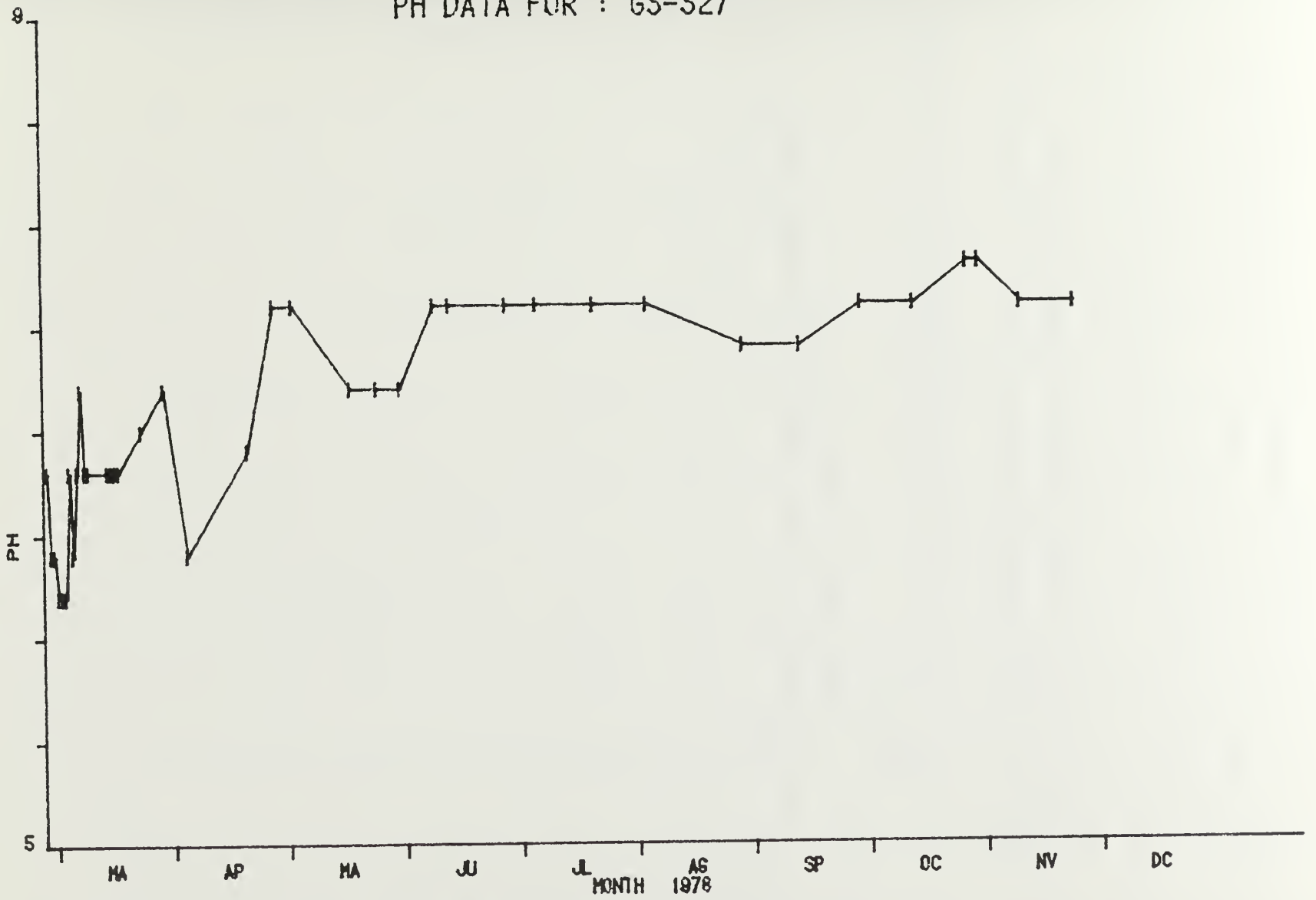

FIGURE 5-51 PH Data for Alluvial Hole No. G-S S27 for 1978, Tract C-a

The water level data for G-S S27 indicate a close association with the discharge from the dewatering program. Water levels begin rising in March when the discharges were increased and show major rises in April when discharges were again increased. During May, when the discharge from the dewatering operation was stabilized, the water levels tended to stabilize in G-S S27. In July, when the discharges were reduced by approximately 1/3, the water level began to decline and has shown a slight and steady decline since that time. The temperature, conductivity and pH data are similar to the data from G-S S11.

TABLE 5-9 WELL DEPTHS AT VARIOUS COMPLETION INTERVALS FOR ALLUVIAL WELLS, TRACT C-a

		LEVEL IN FEET							
Well No.	T.D.*	A	B	C	D	E	F	G	H
G-S S6	12	-	-	-	-	3.5	12	-	-
G-S S7	44	-	-	-	-	12.5	44	-	-
G-S S8	50	-	-	-	-	10	50	-	-
G-S S11	66	34	39	50	58	-	-	-	-
G-S S11A	45	27	37	30	40	-	-	-	-
G-S S13	28	-	-	-	-	8	28	-	-
G-S S14	50	-	-	-	-	10	50	-	-
G-S S24	75	-	-	-	-	55	75	15	35
G-S S25	40	-	-	-	-	30	40	-	-
G-S S26	48	31	34	43	48	-	-	-	-
G-S S27	104	40	45	88	93	-	-	-	-
G-S S27A	16	5	15	-	-	-	-	-	-
G-S S28	35	10	15	25	30	-	-	-	-
G-S S28A	36	11	16	26	31	-	-	-	-
G-S S29	43	15	20	33	38	-	-	-	-
G-S S29A	44	17	22	34	39	-	-	-	-

*TOTAL DEPTH

In summary, the water level, temperature, conductivity and pH of these alluvial monitor holes appear to have responded quite predictably to oil shale operations and with the exceptions noted above, are within the ranges established during the baseline period. The greatest change in any one of these parameters was the rise in water level in G-S S27 of nearly 20 feet in response to the dewatering program discharges.

b. Chemical Parameters - Detailed water quality data collected from the alluvial aquifers from 01 June through 30 November 1978 are included in Appendix 5-2 of this report. A summary of the data collected and received from 01 December 1977 through 03 November 1978 from wells G-S S7, G-S S8, G-S S11, and G-S S27 is presented in Appendix 5-2.1

TABLE 5-10 PHYSICAL AND CHEMICAL CONSTITUENTS COLLECTED DURING THE MDP PROGRAM (1977-78) WHICH VARIED SIGNIFICANTLY FROM BASELINE DATA

Hole: Parameter	G-S S7	G-S S8	G-S S11	G-S S24
Depth to Water			+	+
COD	+			
pH			+	+
Nitrite		+		+
DOC		+	+	
Chloride	+			
Boron		+		
Copper			+	
Flouride		+		
Lead			+	
Strontium	+	+	+	+
Zinc				+
Aluminum		+		
Cross	+			
Nitrate			+	

+ indicates significant variance

Table 5-10 compares the data collected during the baseline period for each of the four holes studied (G-S S7, G-S S8, G-S S11, and G-S S24) with the data collected from the same holes during the 1977-78 monitoring period. The results of the F-Test are given for each parameter which failed at the 95 percent confidence level and one degree of freedom. It should be noted that the only item or parameter that failed on each of the holes was Strontium. The reason for this variance is that, during the baseline, Strontium was analyzed using qualitative spectrographic methods while, during the MDP monitoring, the analysis used the more accurate atomic absorption method.

Depth and pH for alluvial monitor holes G-S S11 and G-S S24 failed to pass the F-Test because the data collected during the MDP was higher than that collected during the baseline. Other parameters which did not pass demonstrated significantly lower MDP values than baseline values.

Control Stations G-S S7 and G-S S8 are not likely to have been affected by the activities on Tract C-a. Therefore, significant differences between baseline values and MDP values measured at these stations are probably caused by natural variations.

The trilinear diagram (Figure 5-52), when compared to the trilinear diagram of the combined alluvial aquifer as presented in the Final Environmental Baseline Report, has the same distribution with the exception of one outlyer. That outlyer results from an analysis of water quality from one of the new holes, G-S S27A. This hole was not included in the baseline analysis. Results from this hole will be discussed later.

A correlation analysis for water quality constituents measured during the current year (Figure 5-53) was performed, and the results compared to a similar analysis performed on baseline data. A positive (+) sign indicates a direct correlation, significant at the 5 percent level. A minus (-) sign is an inverse correlation significant at the 5 percent level. Three correlations have been circled, these are the correlations that are reversed (in sign) from the correlation matrix prepared from baseline data. These correlations are: temperature and mercury, ammonia and sulfide, and ammonia and lead. The

FIGURE 5-52 Combined (G-S S7, G-S S8, G-S S11, G-S S24, G-S S27, G-S S27A, G-S S28D, G-S S28D) Alluvial Aquifer Trilinear Diagram for October 1977-October 1978 Data

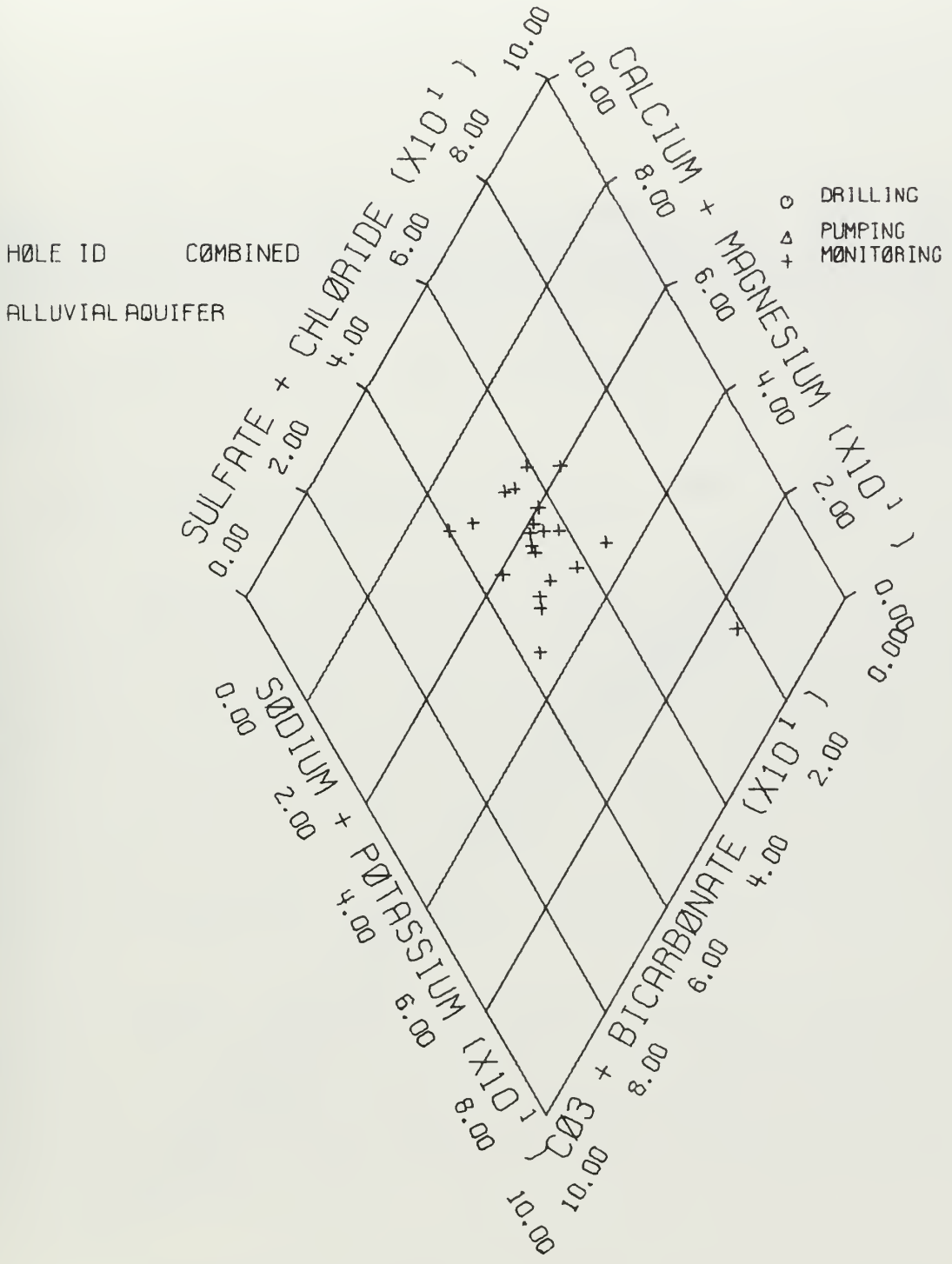

FIGURE 5-53 ALLUVIAL AQUIFER WATER QUALITY MONITORING PROGRAM SUMMARY CORRELATION MATRIX

reversal in correlation noted for these constituents is probably related to the limited amount of data that were collected. A comparison of all of the alluvial holes, including those in the MDP program, does not indicate that these values have a disagreement in the sign.
The correlation matrix inclusive for all holes has eight correlations which are reversed in sign from the baseline data. It should be noted, however, that there are seven holes included in this correlation matrix which were not included in the baseline program. It is felt that this is the reason for the correlation reversals.

A study was conducted on GS-S27, which had nearly a 20-foot rise in water level as a result of the dewatering program discharge. The results of this study indicate that as water level rose, the following constituents varied as indicated: calcium, fluoride and Gross Alpha decreased, while carbonate, magnesium and DOC increased. These variations were not extreme but were consistent.

B. Deep Oil (Upper and Lower) Shale Aquifers

1. Objectives - During the MDP the water levels and water quality of the deep (upper and lower) oil shale aquifers have been analyzed and compared to water levels and water quality existing prior to mining and development operations. The objective of this process is to detect changes in the character of the aquifer, determine if the changes are significant, and analyze the changes to determine if they are caused by mining or development operations, such as dewatering and reinjection. In addition, it is the object of this monitoring program to determine if the project is adhering to lease and permit requirements, applicable laws, and regulations.

2. Methods - The methods followed for collection of these data were described in the RBOSC MDP Monitoring Report 2, and are not repeated herein. The locations of the monitoring holes are found on Figure 5-1. Revised completion diagrams for all monitoring holes included in the current program are presented in Appendix 5-2.6.

3. Results and Discussion

a. Physical parameters - Table 5-11 shows the monitoring schedule of the deep oil shale aquifer (upper and lower) monitoring holes for

TABLE 5-11 DEEP WELL MONITORING SUMMARY

	1977										1978										
Well #	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
AM 2A		X+						X+	X+			X+	X								
AM 3		X+						X+				X									
CE 702			X+					X+	X+	X+	X+	X+	X+	X+							
CE 707		X+						X+				X									
CE 708		X+						X+				X									
CE 709		X+						X+				X									
G-S M1		X+						X+	X+		X	X	X	X+	X	X+ B	X	X	X		X
G-S M2		X+	X+					X+	X+							B					
G-S M3		X+						X+	X+												
G-S M4		X+						X+	X+			X	X	X+	X	X+ B	X	X	X	X	X
G-S M5	X	C	X					X	X												
G-S 1		X+						X+				X									
G-S 2-3		X+						X+				X									
G-S 4-5	X+	X+	X+			X+		X+		X+		X									
G-S 6		X+						X+													
G-S 9		X+						X+	X+			X									
G-S 10		X+						X+	X+			X									
G-S 11		X+						X+	X+		X	X+	X	X+	X	X+ B	X	X			
G-S 12		X+						X+	X+			X									
G-S 13		X+						X+	X+			X									
G-S 15		X+						X+	X+		X	X	X+	X+	X+	X+ B	X+	X+	X+	X+	X+
TO-1		X+						X+				X									
TO-2		X+						X+				X+									

X+ = Both upper and lower water level measured
X = Upper aquifer water level measured
B = Baseline water quality
C = Water level, conductivity, temperature, pH

environmental purposes. Monitoring was discontinued at G-S 11 in August 1978 for conversion of G-S 11 to an upper aquifer injection hole. Testing work conducted in August and September prevented the hole from being monitored for environmental purposes. RBOSC has proposed to monitor AM-3 as a substitute for G-S 11.

Data indicate that the water level in the upper aquifer of G-S 11 was rising slowly and steadily after the baseline aquifer testing was completed in May 1975. The data collected since November of 1976 indicate that this trend has continued. Figure 5-54, the water level hydrograph for G-S 11 upper aquifer, does not indicate any significant water level responses as a result of the dewatering or reinjection programs.

Water levels in the upper aquifer at monitor hole G-S 15 also showed a general rise during the baseline period (Figure 5-55). This rise continued throughout the interim period and until March 1978. During the period of March 1978 through November 1978 a consistent decline in water level can be noted. The mean water level during the baseline period was 273.77 feet. By 27 November 1978, the water level had dropped to 288.57 feet below the surface from the previously recorded high on 15 February 1978 of 270.12 feet. The water level data from the upper aquifer of G-S 15 indicates that this monitor hole responds quite rapidly to the dewatering program. In other words, as the dewatering rates are increased, the water levels in G-S 15 decline. The water levels do not appear to respond to the reinjection of the upper aquifer water back into the upper aquifer.

The water levels in G-S 15 lower aquifer show opposite movements from those of the upper aquifer at the same location (Figure 5-56). The mean water level during the baseline period was 366.64 feet. From July 1975 through November 1976 the water level showed a steady decline in this monitor hole. The decline appears to have continued until October 1977 to a depth of 380.19 feet, the lowest level ever recorded for the lower aquifer at G-S 15. Over a six-week period, from late November until early January, the water level rose approximately 5-1/2 feet. However, by late February 1978 the water levels had dropped 3 feet from the January value. This decreasing trend continued until the second week in March 1978. Since that time, the water level in the lower

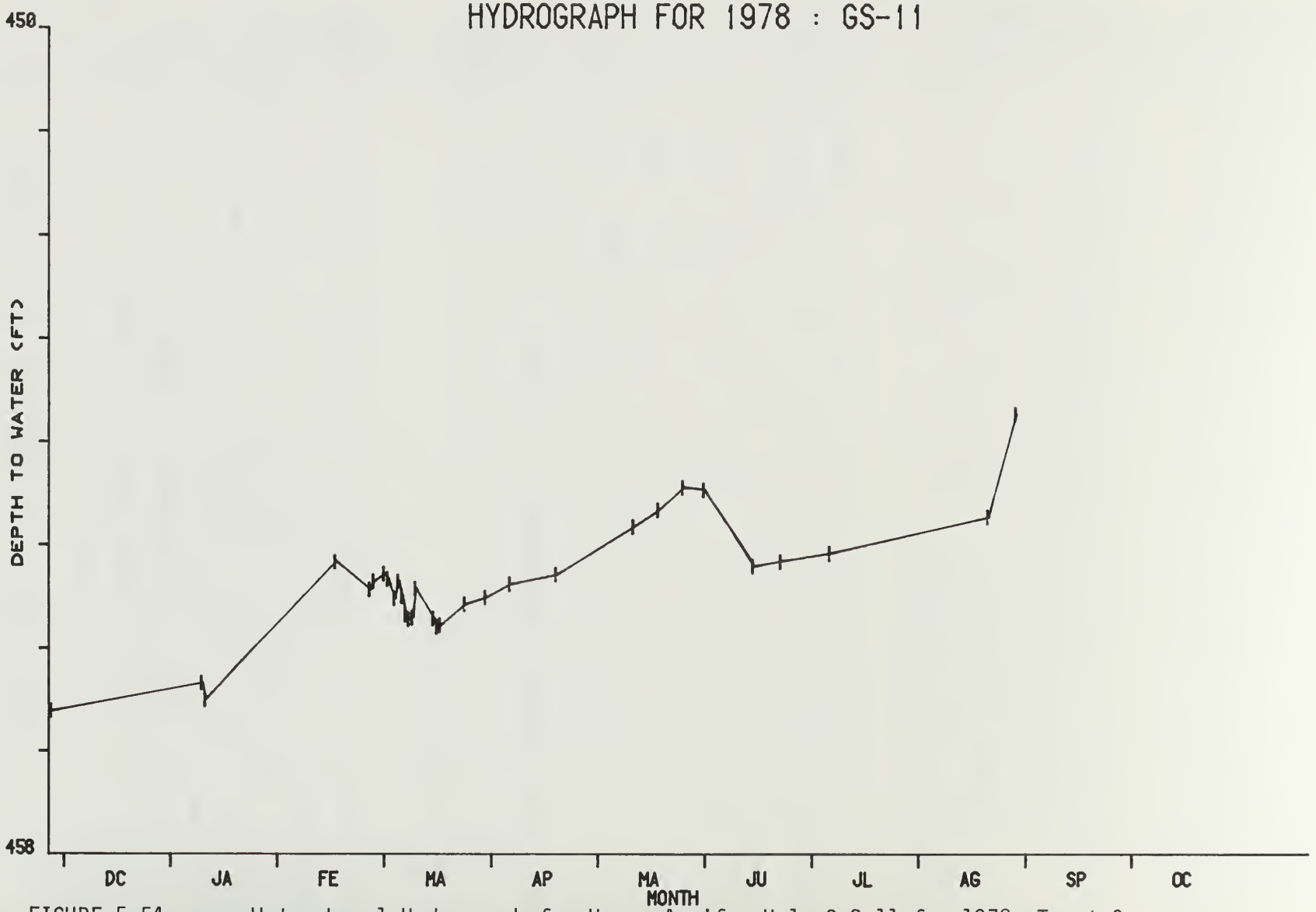

FIGURE 5-54 Water Level Hydrograph for Upper Aquifer Hole G-S 11 for 1978, Tract C-a

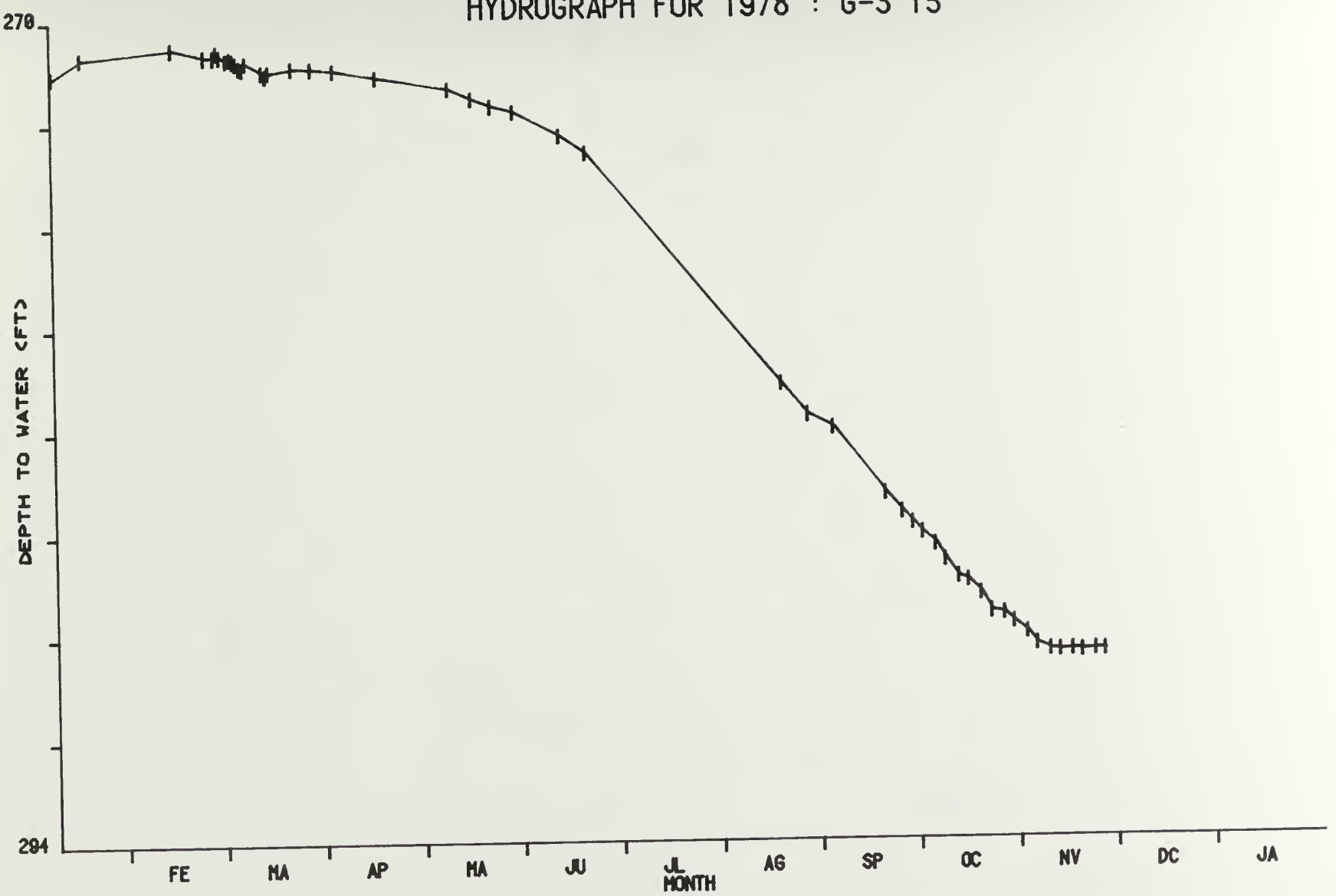

FIGURE 5-55 Water Level Hydrograph for Upper Aquifer Hole G-S 15 for 1978, Tract C-a

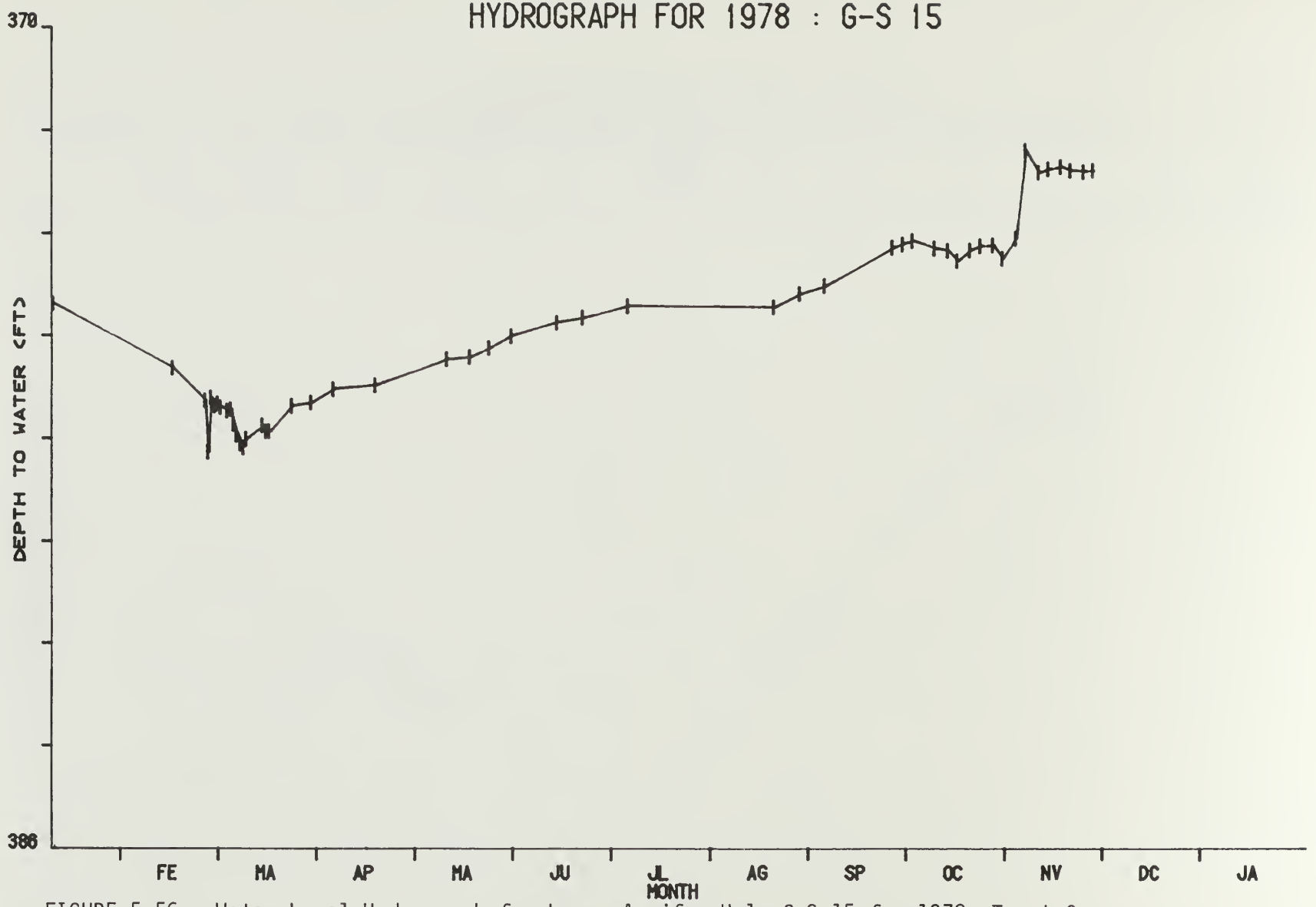

FIGURE 5-56 Water Level Hydrograph for Lower Aquifer Hole G-S 15 for 1978, Tract C-a

aquifer at G-S 15 has generally risen. The behavior of the water level in G-S 15 lower aquifer may be explained by the opening and closing of bore holes from the upper to the lower aquifer. From January 1975 through November 1977, the holes drilled prior to 1975 were packed off allowing the water levels in G-S 15 to recover to normal levels. In December 1977, the packers were removed to ready some monitor holes for injection testing. Once the aquifers were allowed to communicate again, the lower aquifer water level rose. The brief decline of its water level from January to mid-March 1978 represents a recovery from this man-made stress.

The rise in water levels recorded from mid-March 1978 through November 1978 is the result of the injection program. As was established during the baseline and reaffirmed during the MDP, there is a hydrologic connection near the east boundary of Tract C-a between the upper and lower aquifers. The injection of water into the upper aquifer resulted in flow from the upper aquifer to the lower aquifer along this hydrologic connection.

The hydrograph for the upper aquifer G-S M1 for the current year is shown on Figure 5-57. These water level data indicate that the November 1978 level of approximately 625 feet was close to the calculated baseline mean value. The water levels dropped to a new low in July 1978. This water level decline was probably a response to the dewatering program. In July 1978, reinjection of the dewatering water into the upper aquifer was drastically increased. The hydrograph for G-S M1 upper aquifer shows a very favorable response to this increase in reinjection. In fact, new water level highs were recorded from August through December.

The hydrograph for the upper aquifer of GS-M2 of the current year's data, as shown on Figure 5-58, shows a variation in water level between 217 feet and 219 feet. Water levels recorded during the baseline period rose from 253 feet below the surface to 223. These rising water levels reflect the recovery of the upper aquifer from effects of the pre-lease drilling holes previously mentioned. The fluctuations in the water level recorded from February 1978 through November 1978 appear to be natural and not greatly affected by either the dewatering or reinjection programs.

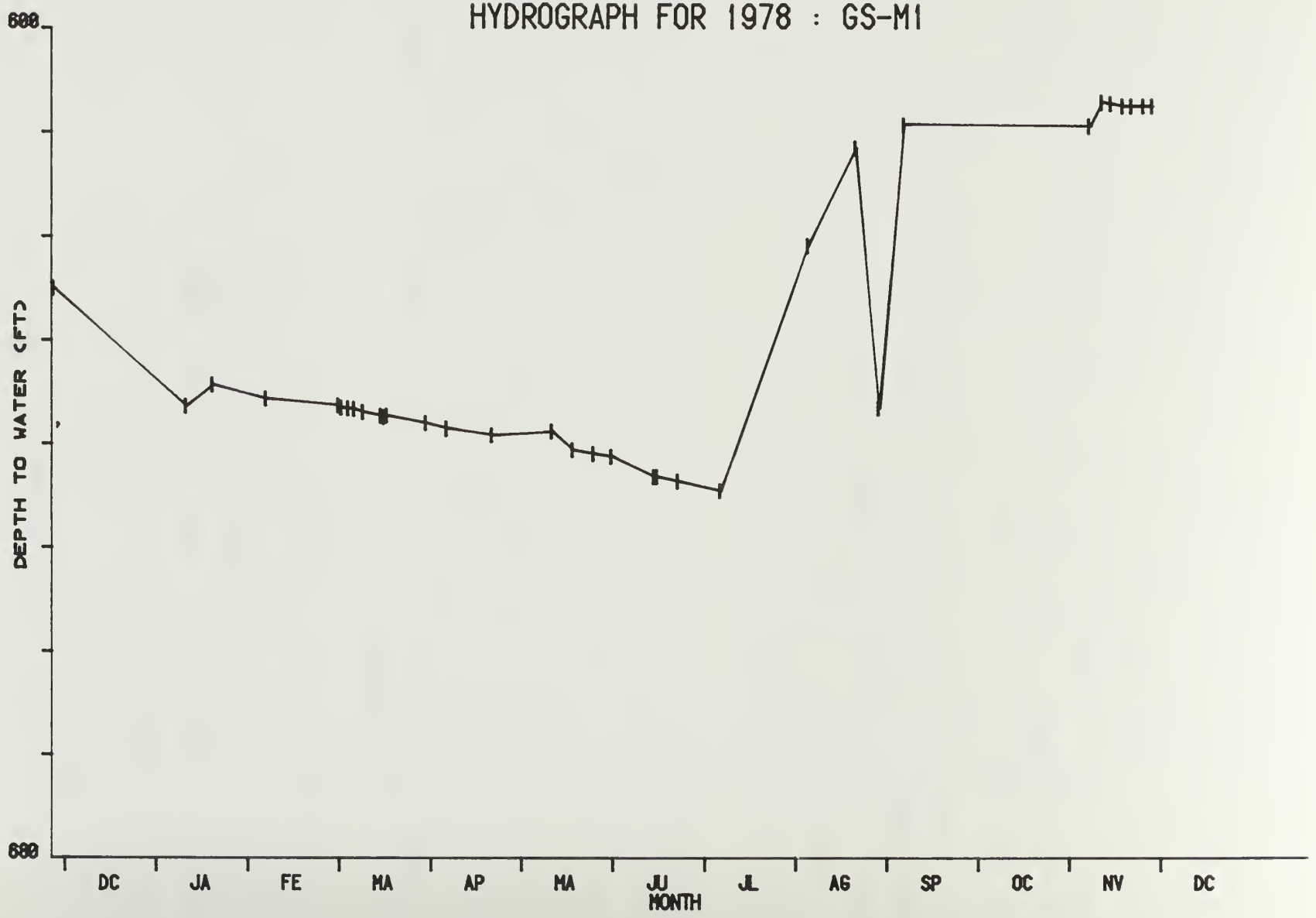

FIGURE 5-57 Water Level Hydrograph for Upper Aquifer Hole G-S M1 for 1978, Tract C-a

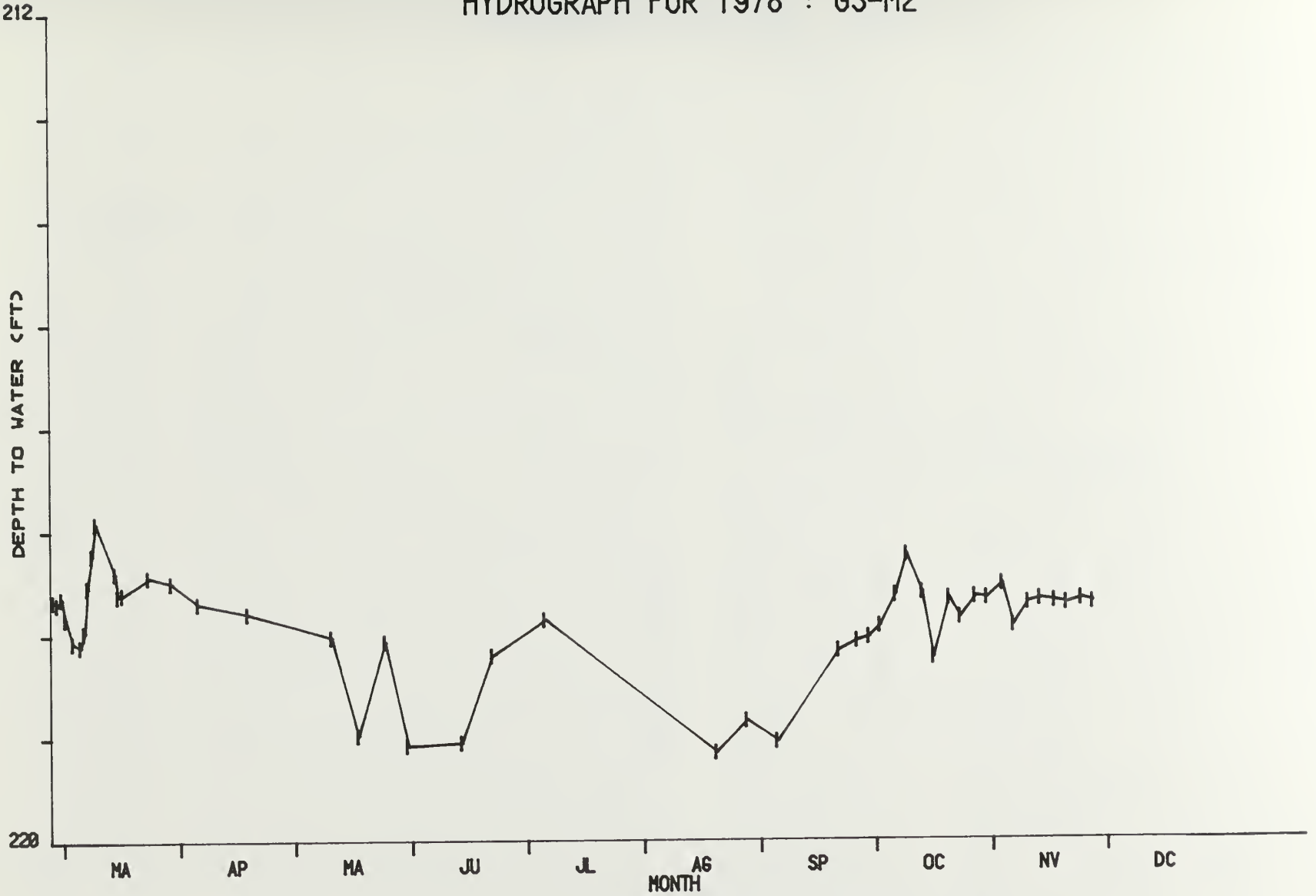

FIGURE 5-58 Water Level Hydrograph for Upper Aquifer Hole G-S M2 for 1978, Tract C-a

The hydrograph for GS-M4 upper aquifer is shown on Figure 5-59. The water levels recorded from the baseline indicate that the water level was generally dropping at the rate of about 2-1/2 feet a year. This trend continued until February 1978, when, in a period of nine months, the water levels dropped approximately 20 feet. The water levels of GS-M4 do not appear to respond to changes in either the dewatering or reinjection rates. The reinjection holes are generally located along the northern tract boundary between the dewatering location and GS-M4. It is possible that the effects of dewatering and reinjection are smoothed by the distance between the three sites. It is also possible that this rapid decrease in water level could be a result of natural phenomena connected with the drought of 1976 and 1977 or with drilling activities off Tract C-a.

In summary, the physical water level data collected from the deep aquifer program indicates that GS-S11 and GS-M2 have not been affected by the dewatering reinjection programs. GS-15 upper and lower aquifer and GS-M1 definitely appear to have responded to the dewatering and reinjection programs. GS-M4 may or may not have been affected by these activities.

b. Chemical Parameters - Results of chemical analyses of upper aquifer water (Table 5-12) were compared with similar data from the baseline period using an F-test (See Appendices 5-2.4 and 5-2.5 for individual constituents analysis and combined aquifer comparisions, respectively). The F-test indicated that boron, bromide, carbonate, mercury, molybdenum, and nitrate did no come from the same populations. All, except carbonate and molybdenum failed the test because they were below detectable limits during the MDP. Molybdenum may have failed to pass the test because of the analytical technique used (spectrographic) during baseline. Carbonate did not pass the F test because of one outlyer resulting from an analysis of water from G-S M1, a value of 96 milligrams per liter. This value is not outside of the range with the values predicted from the baseline for G-S M1, therefore, this failure to pass is predictable.

The trilinear diagram (Figure 5-60) for the 1977-78 upper aquifer data is consistent with the data presented in the baseline report. There are no values which lie outside the pattern or the area of the trilinear diagram presented in the FEBR.

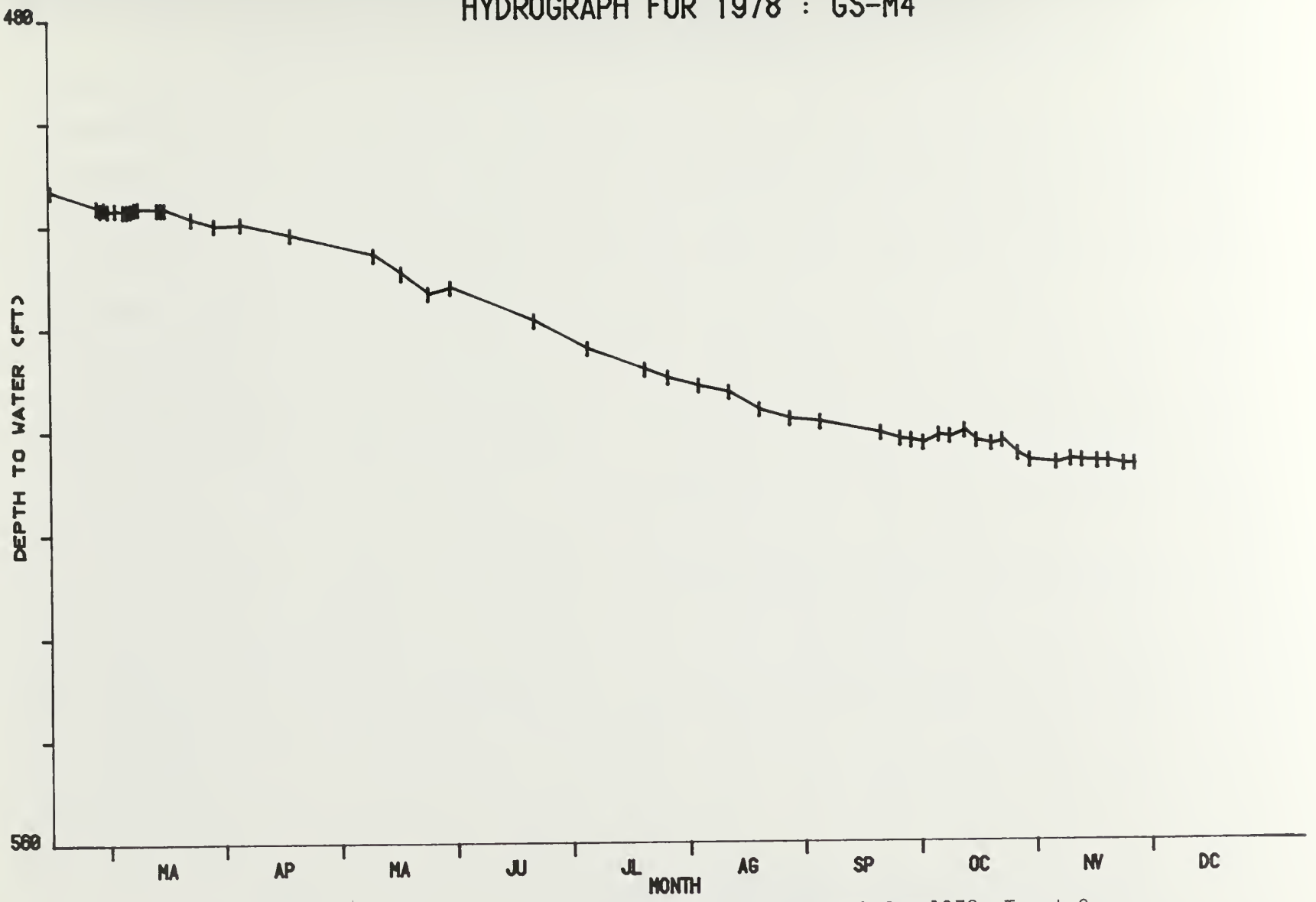

FIGURE 5-59 Water Level Hydrograph for Upper Aquifer Hole G-S M4 for 1978, Tract C-a

TABLE 5-12 Summary of Water Quality Data Collected at Upper Aquifer Holes G-S 15, G-S M1, G-S M2, G-S M4 for June 1978

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AQUIFER U

PARAMETER DESCRIPTION	NUMBER OF ANALYSES	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION	WET SAMPLES 95 CONFIDENCE LIMITS ON MEAN UPPER	LOWER	THEORETICAL PROBABILITY OF BEING LESS THAN OR EQUAL TO VALUE LISTED 25	50	75	90	95
00003& SAMPLE DEPTH, FEET	4	644.01	218.60	411.81	199.75	689.07	134.56	276.98	411.81	546.65	667.89	740.40
00011& TEMPERATURE, WATER DEG. F	4	69.80	56.30	65.30	6.19	73.89	56.71	61.12	65.30	69.48	73.24	75.49
00095* CONDUCTIVITY UMHOS AT 25 DEG C	4	1949.99	1090.00	1614.42	1.31	2342.31	1112.72	1347.14	1614.42	1934.72	2276.67	2509.40
00340* CHEMICAL OXYGEN DEMAND, .25 N K2CR07	4	38.00	10.00	19.03	1.77	42.15	8.59	12.93	19.03	28.01	39.66	48.83
00400& PH STANDARD UNITS	4	8.00	7.40	7.62	0.26	7.99	7.26	7.45	7.62	7.80	7.96	8.06
00410* ALKALINITY, TOTAL MG-L AS CACO3	4	445.00	295.00	366.87	1.20	470.29	286.20	325.14	366.87	413.96	461.45	492.41
00440* BICARBONATE ION MG-L AS HCO3	4	545.00	260.00	406.33	1.38	634.74	260.11	327.09	406.33	504.76	613.49	689.39
00445* CARBONATE ION MG-L AS CO3	4	96.00	0.10	6.75	19.08	404.21	0.11	0.92	6.75	49.38	295.71	862.41
00540* DISSOLVED SOLIDS RDE AT 178 DEG C, M	4	1300.00	670.00	1062.01	1.37	1636.69	689.11	860.56	1062.01	1310.62	1583.52	1773.16
00613* NITROGEN, NITRITE, DISSOLVED MG-L AS N	4	0.05	0.01	0.01	2.24	0.05	0.00	0.01	0.01	0.03	0.04	0.06
00681* CARBON, ORGANIC, DISS MG-L AS C	4	4.50	1.60	3.23	1.61	6.25	1.67	2.35	3.23	4.46	5.94	7.06
00720* CYANIDE MG-L AS CN	4	0.01	0.01	0.01	1.00							
00746* SULFIDE, DISSOLVED MG-L AS S	4	2.20	0.20	0.43	3.10	2.08	0.09	0.20	0.43	0.93	1.85	2.79
00915* CALCIUM, DISSOLVED MG-L AS CA	4	48.00	8.20	25.65	2.26	79.33	8.29	14.81	25.65	44.42	72.78	97.78
00925* MAGNESIUM, DISSOLVED MG-L AS MG	4	135.00	23.00	76.23	2.27	238.40	24.37	43.78	76.23	132.72	218.52	294.44
00930* SODIUM, DISSOLVED MG-L AS NA	4	235.00	190.00	211.72	1.10	242.92	184.52	198.03	211.72	226.36	240.38	249.18
00935* POTASSIUM, DISSOLVED MG-L AS K	4	4.00	2.00	2.76	1.33	4.10	1.86	2.28	2.76	3.35	3.98	4.41

TABLE 5-12 (Continued)

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AQUIFER U

PARAMETER DESCRIPTION	NUMBER OF ANALYSES	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION	WET SAMPLES 95 CONFIDENCE LIMITS ON MEAN UPPER	LOWER	THEORETICAL PROBABILITY OF BEING LESS THAN OR EQUAL TO VALUE LISTED 25	50	75	90	95
00940* CHLORIDE, DISSOLVED MG-L AS CL	4	14.00	3.50	8.37	1.83	19.30	3.63	5.57	8.37	12.56	18.11	22.53
00945* SULFATE, DISSOLVED MG-L AS SO4	4	615.00	175.00	428.20	1.82	985.30	186.09	285.52	428.20	642.17	924.54	1149.69
00950* FLUORIDE, TOTAL MG-L AS F	4	1.40	0.20	0.51	2.44	1.75	0.15	0.28	0.51	0.93	1.60	2.20
00955* SILICA, DISSOLVED MG-L AS SIO2	4	8.00	2.00	5.43	1.96	13.77	2.14	3.45	5.43	8.54	12.83	16.36
01000* ARSENIC, DISSOLVED UG-L AS AS	4	10.00	10.00	10.00	1.00							
01020* BORON, DISSOLVED UG-L AS B	4	100.00	100.00	100.00	1.00							
01025* CADMIUM, DISSOLVED UG-L AS CD	4	10.00	10.00	10.00	1.00	10.03	9.97	9.98	10.00	10.02	10.03	10.04
01030* CHROMIUM, DISSOLVED UG-L AS CR	4	10.00	10.00	10.00	1.00	10.03	9.97	9.98	10.00	10.02	10.03	10.04
01046* IRON, DISSOLVED UG-L AS FE	4	370.00	50.00	82.47	2.72	330.77	20.56	41.97	82.47	162.05	297.48	427.78
01049* LEAD, DISSOLVED UG-L AS PB	4	10.00	10.00	10.00	1.00							
01080* STRONTIUM, DISSOLVED UG-L AS SR	4	4199.98	900.00	2159.18	1.90	5258.52	886.57	1400.53	2159.18	3328.78	4912.94	6200.71
01090* ZINC, DISSOLVED UG-L AS ZN	4	100.00	10.00	56.23	3.16							
01106* ALUMINUM, DISSOLVED UG-L AS AL	4	400.00	300.00	372.24	1.15	454.42	304.92	337.82	372.24	410.16	447.55	471.52
01145* SELENIUM, DISSOLVED UG-L AS SE	4	10.00	10.00	10.00	1.00							
01503 GROSS ALPHA, DISSOLVED PC-L	1	0.70	0.70									
70507* PHOSPHORUS, TOTAL ORTHO MG-L AS P	4	0.20	0.10	0.12	1.41							
71846* NITROGEN, AMMONIA DISS MG-L AS NH4	4	1.40	0.30	0.44	2.16	1.28	0.15	0.26	0.44	0.74	1.18	1.57

TABLE 5-12 (Continued)

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AQUIFER U

PARAMETER	DESCRIPTION	NUMBER OF ANALYSES	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION	WET SAMPLES 95 CONFIDENCE LIMITS ON MEAN UPPER	LOWER	THEORETICAL PROBABILITY OF BEING LESS THAN OR EQUAL TO VALUE LISTED 25	50	75	90	95
71851*	NITROGEN, NITRATE DISS MG-L AS NO3	4	0.10	0.10	0.10	1.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10
71870*	BROMIDE MG-L	4	0.10	0.10	0.10	1.00							
71890*	MERCURY DISSOLVED UG-L AS HG	4	1.00	1.00	1.00	1.00							

END OF AQUIFER U WET SAMPLES REPORTING PERIOD IS 06-26-78 THRU 06-27-78

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* -- ESTIMATE USING METHOD OF MOMENTS
& -- NO LOG TRANSFORM
VALUES OF 99999.0 ARE MAJOR CONCENTRATIONS

TABLE 5-12 (Continued)

H20QASA-2 REPORT DATE 01-17-79 PAGE 1

AQUIFER U

SPECTROGRAPHIC SAMPLES

PARAMETER DESCRIPTION	NUMBER OF ANALYSES	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION	95 CONFIDENCE LIMITS ON MEAN UPPER	95 CONFIDENCE LIMITS ON MEAN LOWER	THEORETICAL PROBABILITY OF BEING LESS THAN OR EQUAL TO VALUE LISTED 25	50	75	90	95
00003& SAMPLE DEPTH, FEET	4	644.01	218.60	411.81	199.75	689.07	134.56	276.98	411.81	546.65	667.89	740.40
00011& TEMPERATURE, WATER DEG. F	4	69.80	56.30	65.30	6.19	73.89	56.71	61.12	65.30	69.48	73.24	75.49
01040 COPPER, DISSOLVED UG-L AS CU	1	1.00	1.00									
01056* MANGANESE, DISSOLVED UG-L AS MN	4	10.00	1.00	1.78	3.16	8.79	0.36	0.82	1.78	3.87	7.78	11.82
01060* MOLYBDENUM, DISS UG-L AS MO	3	100.00	1.00	4.64	14.28	613.76	0.04	0.77	4.64	27.93	140.28	368.25
01130 LITHIUM, DISSOLVED UG-L AS LI	1	1.00	1.00									

END OF AQUIFER U SPECTROGRAPHIC SAMPLES REPORTING PERIOD IS 06-26-78 THRU 06-27-78

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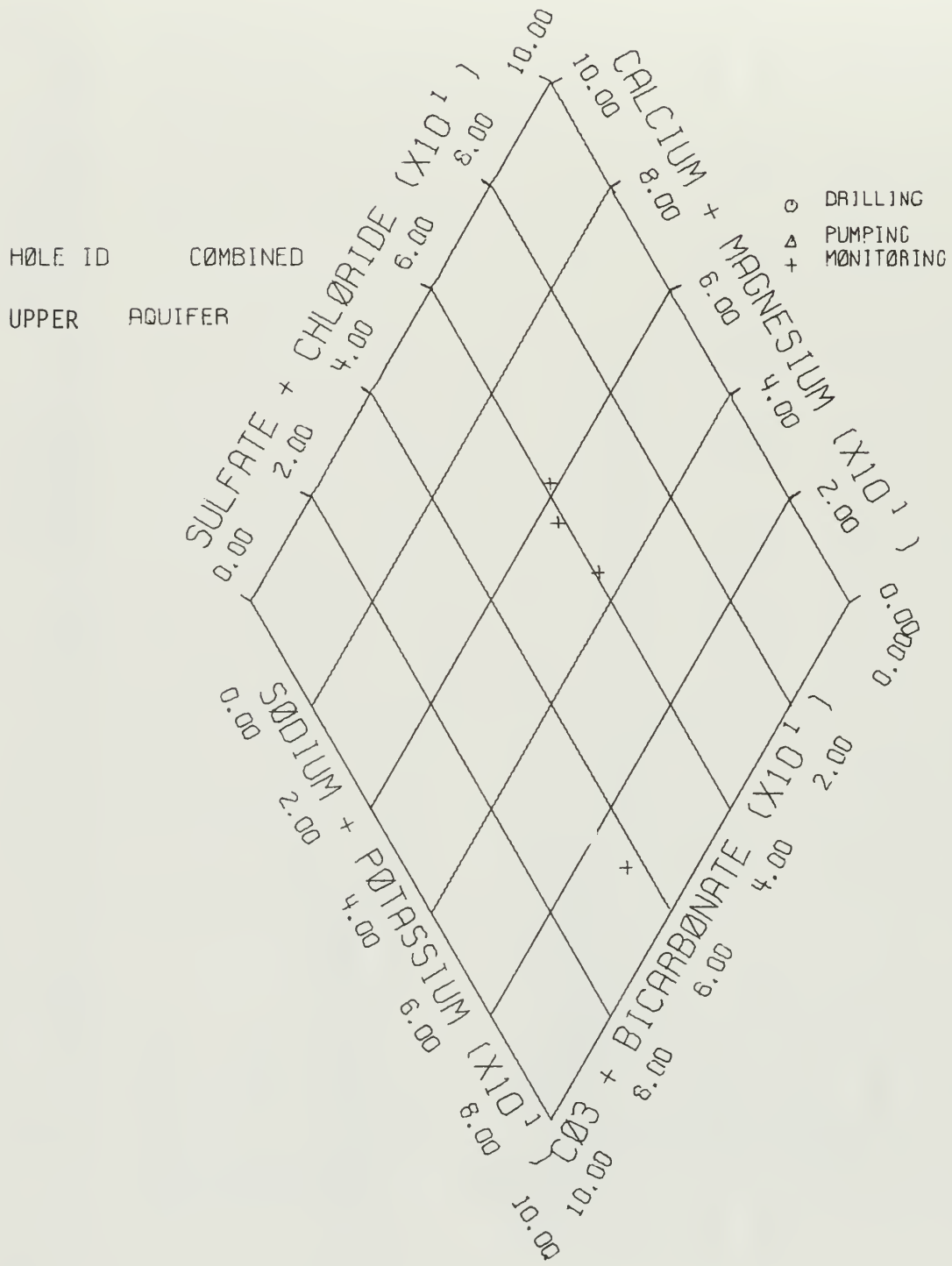
* -- ESTIMATE USING METHOD OF MOMENTS
& -- NO LOG TRANSFORM
VALUES OF 99999.0 ARE MAJOR CONCENTRATIONS

FIGURE 5-60 Combined (G-S 15, G-S M1, G-S M2, G-S M4)
Upper Aquifer Trilinear Diagram for June 1978



The correlation matrix for the upper aquifer indicates that at four separate comparisons, sulfate had a reversal in sign (Figure 5-61). The only other two reversals were for sodium, temperature, and magnesium flouride. These minor deviations are within the acceptable limits.

5.3 MDP PUMP TEST MONITORING

A. Surface Water

1. Objectives - Surface waters are monitored during pump tests to determine the impact of pump tests on surface water quality and quantity.

2. Methods - The methods followed for collection of these data were described in RBOSC Monitoring Report 2 and are not repeated herein. Figure 5-62 shows the locations of the MDP Pump Test Monitoring Sites.

3. Results and Discussions - Table 5-13 is a summary of the surface water monitoring program for the MDP Pump Testing. Upper Yellow Creek did not contain water after installation of the station; however, flow was noted in the field during early March.

Flow, temperature, conductivity, and pH measurements are shown on Figures 5-62 through 5-69 for 84 Ranch and Station 16, respectively.

B. Erosion and Sedimentation Stations

1. Objectives - Erosion and sedimentation are monitored to detect changes in stream channel caused by pump test discharges.

2. Methods - The methods followed for collection of these data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion - Table 5-14 provides an erosion and sedimentation pump test monitoring summary while Figures 5-70 through 5-82 show four cross-sections for each of the sediment and erosion locations in the stream channel. The first cross-section represents the earliest data; the fourth cross-section represents the latest. The two middle cross-sections

represent data between the extremes. Cross-sections for each of the data collections are shown in the Appendix of this report.

Because of the changes in the discharge point, some of the stations have been moved. Station 1 was covered up as were the two B Stations. At the present time, the following stations are still in existence:

STATION #	LOCATION DESCRIPTION
1a	Above the discharge point
3	At G-S S25
4	Above the confluence of Dry Fork
5	Below the confluence of Dry Fork
6	One-third mile below the confluence with Dry Fork
7	At G-S S27
8	At USGS gaging station Corral Gulch each of Tract C-a
9	At G-S S11
10	At G-S S24
11	At County Line Road 24

TABLE 5-13 SURFACE WATER MDP PUMP TEST MONITORING SUMMARY

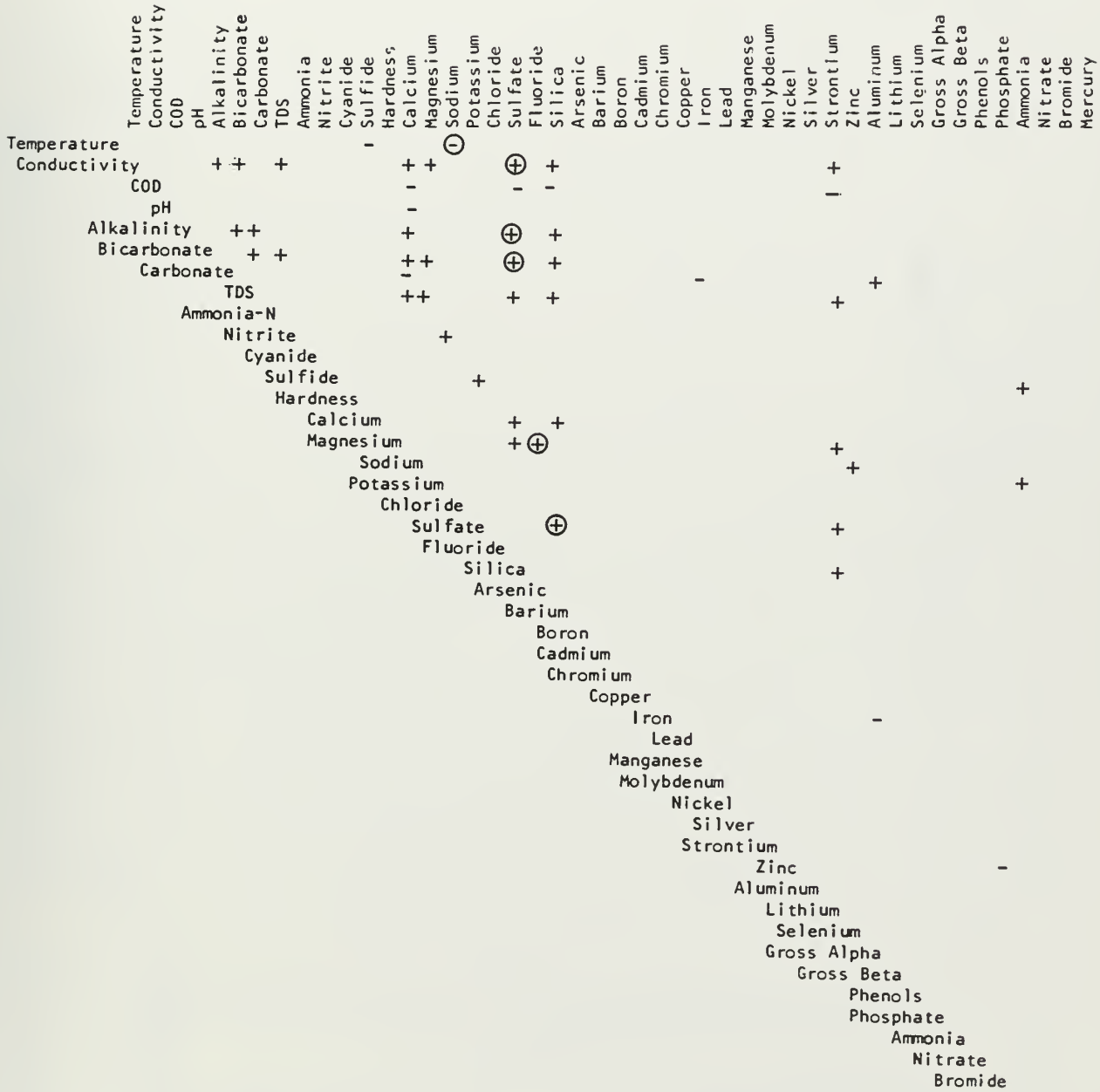
	1978									
Location	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
84 Ranch	X	X	X	X	X	X	X	X		X
	C	C	C	C	C	C	C	C		C
Upper Yellow Creek at Square S Ranch										
Lower Yellow Creek					X	X	X	X		X
25 mi. downstream					C	C	C	C		C
from Pinto Gulch		X	X	X	D		D	D	D	D

X = Flow recording during entire month
I = Intermittent flow recorded during month
C = Conductivity, Temperature, pH and Flow

FIGURE 5-61

UPPER AQUIFER WATER QUALITY MONITORING PROGRAM SUMMARY

CORRELATION MATRIX



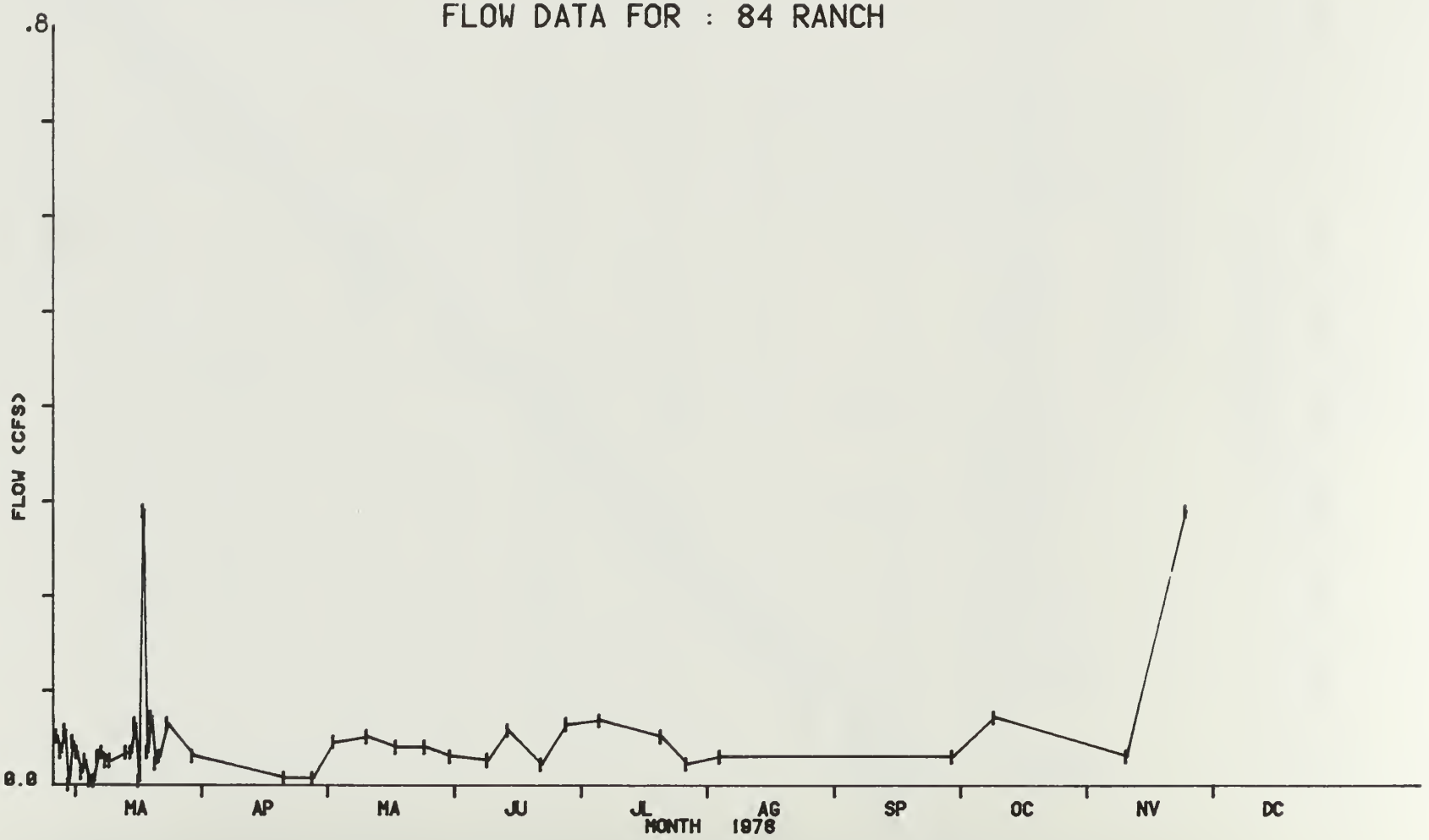


FIGURE 5-62 Flow Data for 84 Ranch Surface Gaging Station, Tract C-a, 1978

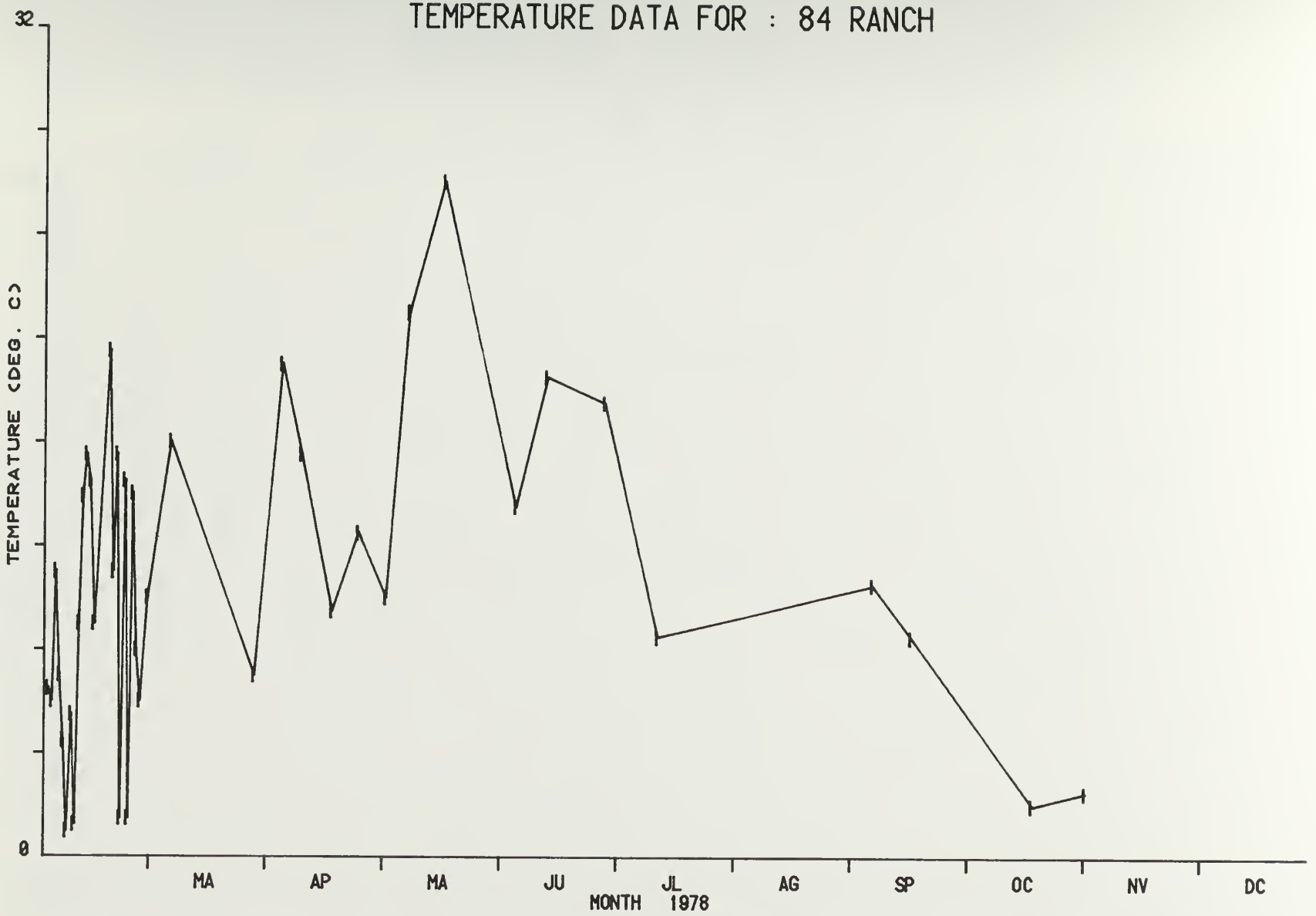


FIGURE 5-63 Temperature Data for 84 Ranch Surface Gaging Station, Tract C-a, 1978

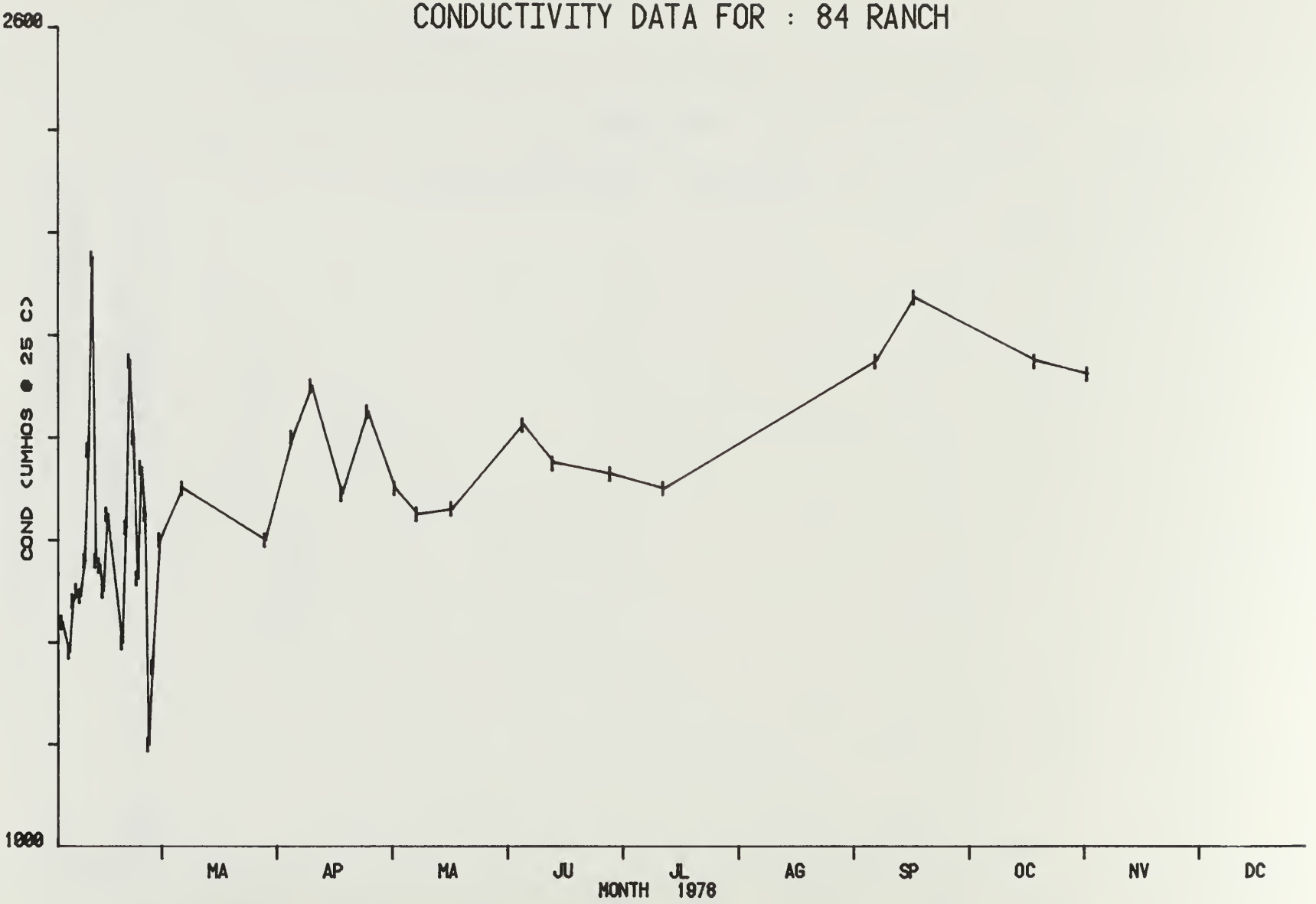


FIGURE 5-64 Conductivity Data for 84 Ranch Surface Gaging Station, Tract C-a, 1978

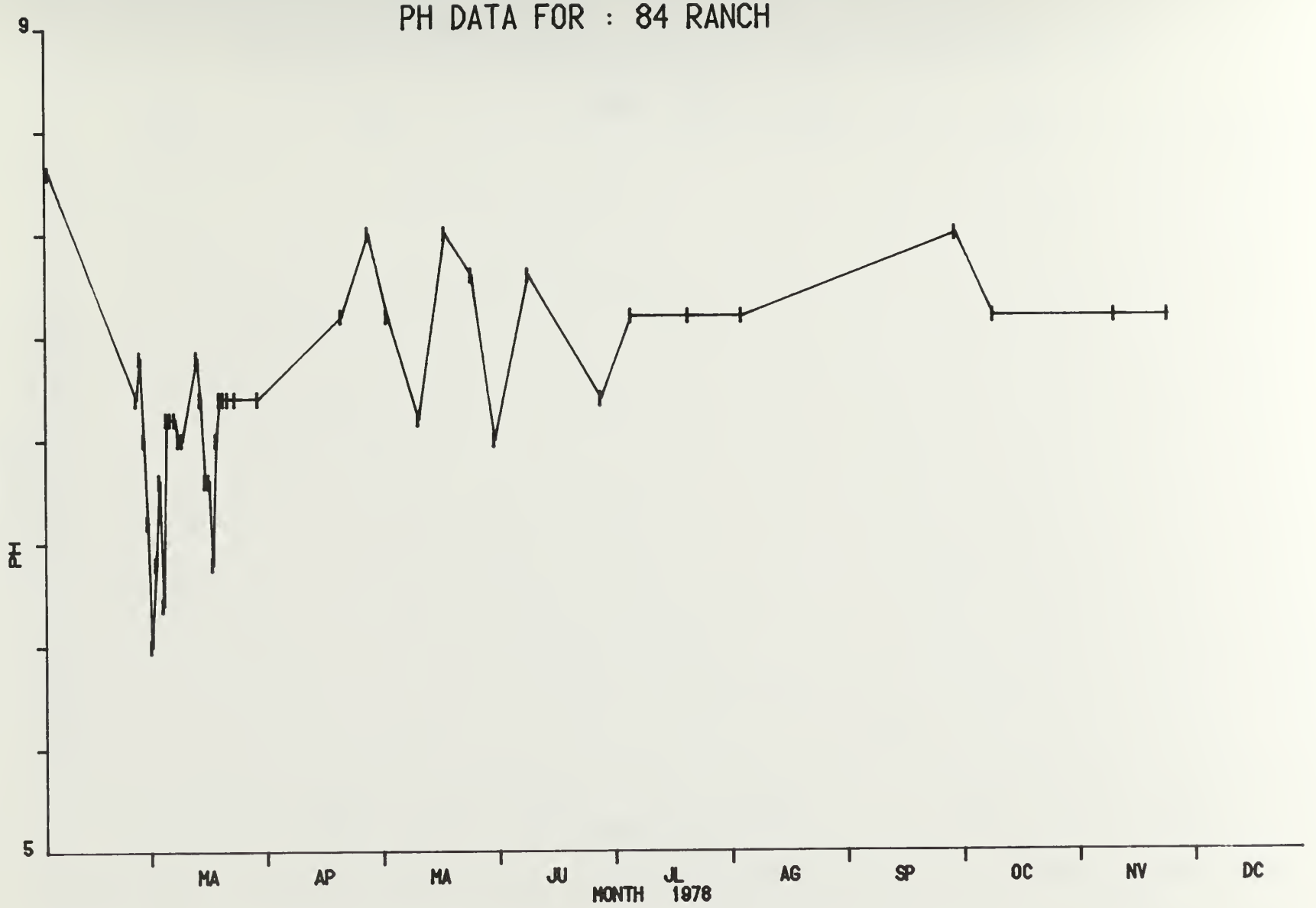


FIGURE 5-65 PH Data for 84 Ranch Surface Gaging Station, Tract C-a, 1978

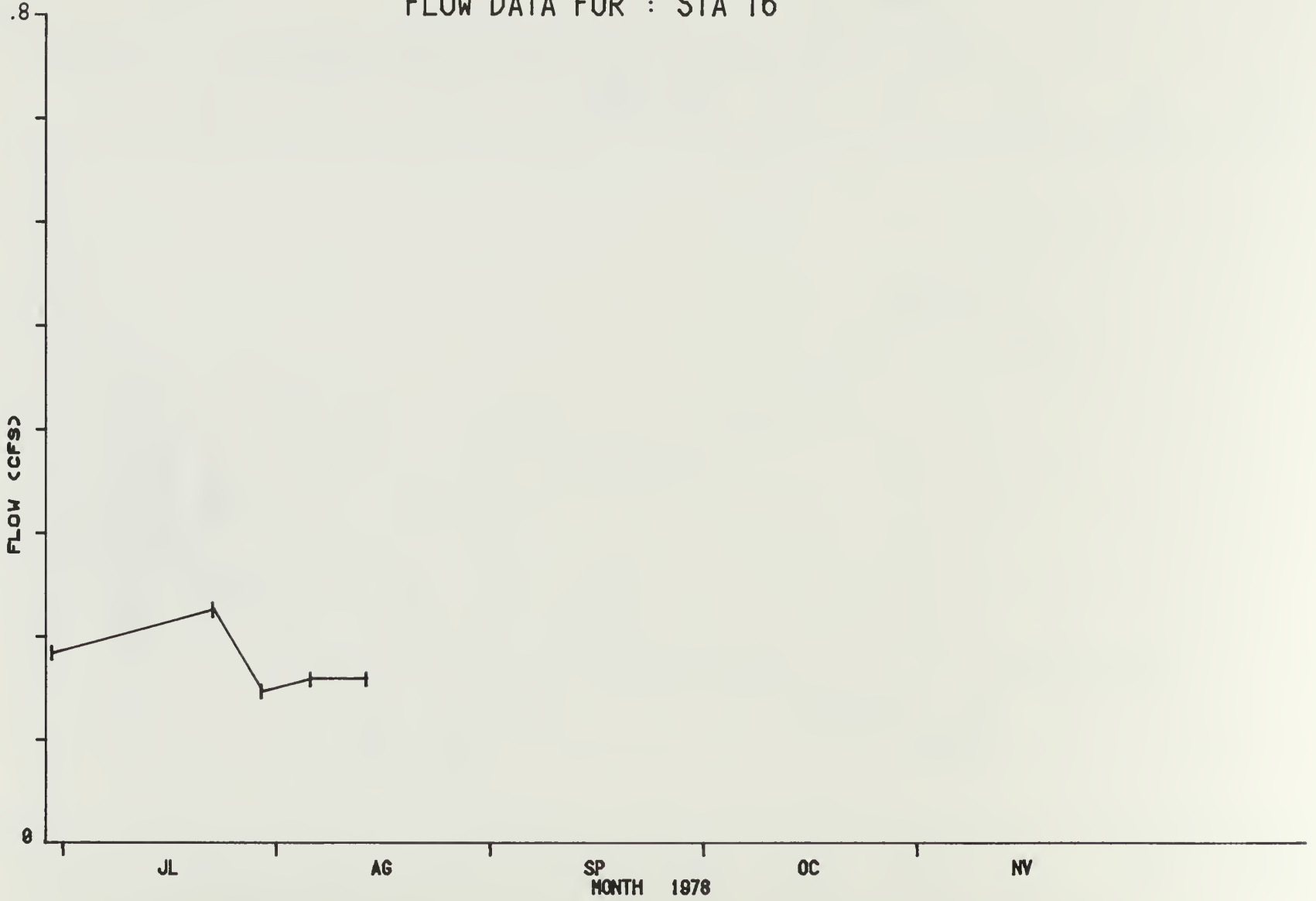


FIGURE 5-66 Flow Data for Surface Gaging Station No. 16, Tract C-a, July-August 1978

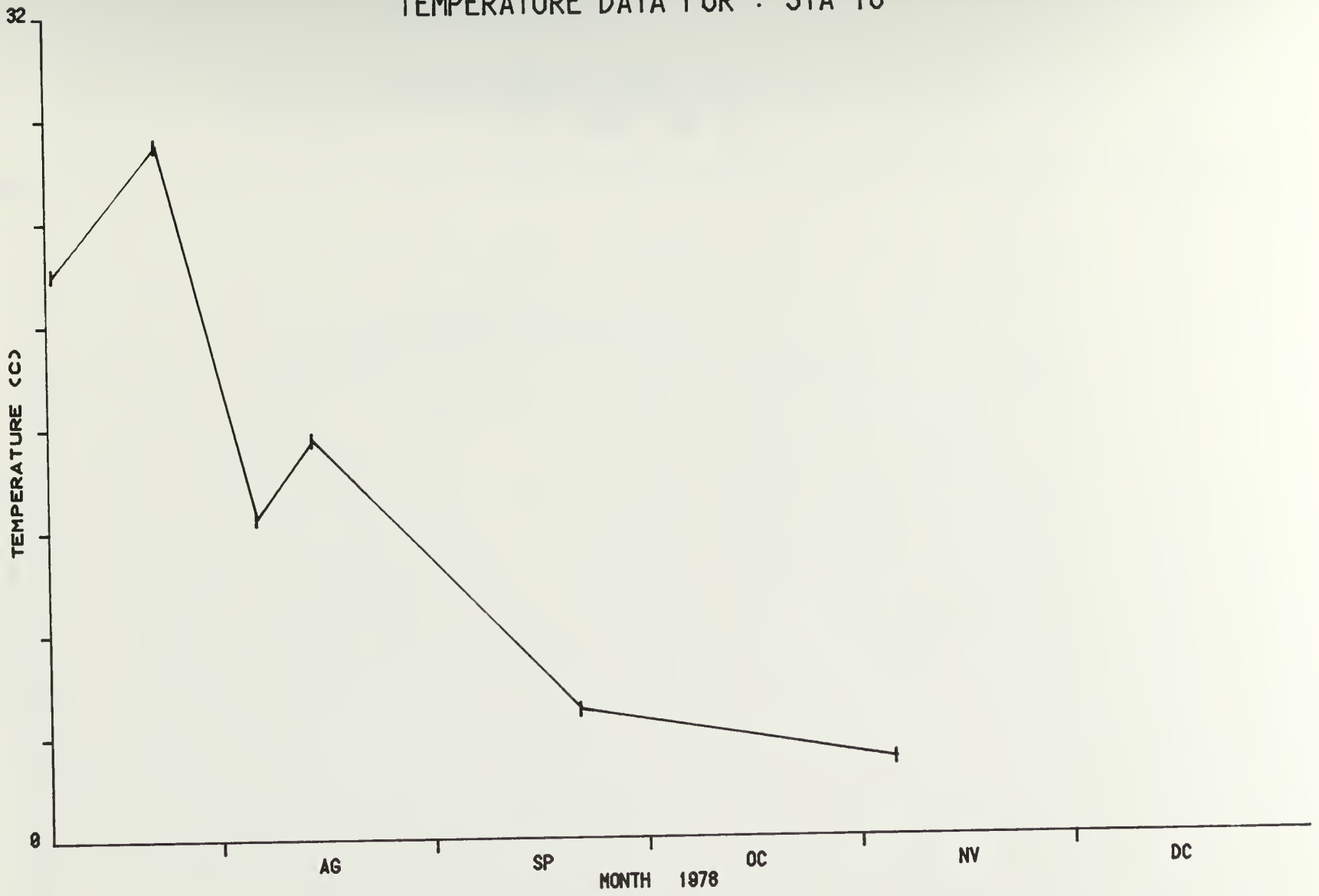


FIGURE 5-67 Temperature Data for Surface Gaging Station No. 16, Tract C-a, August-November 1978

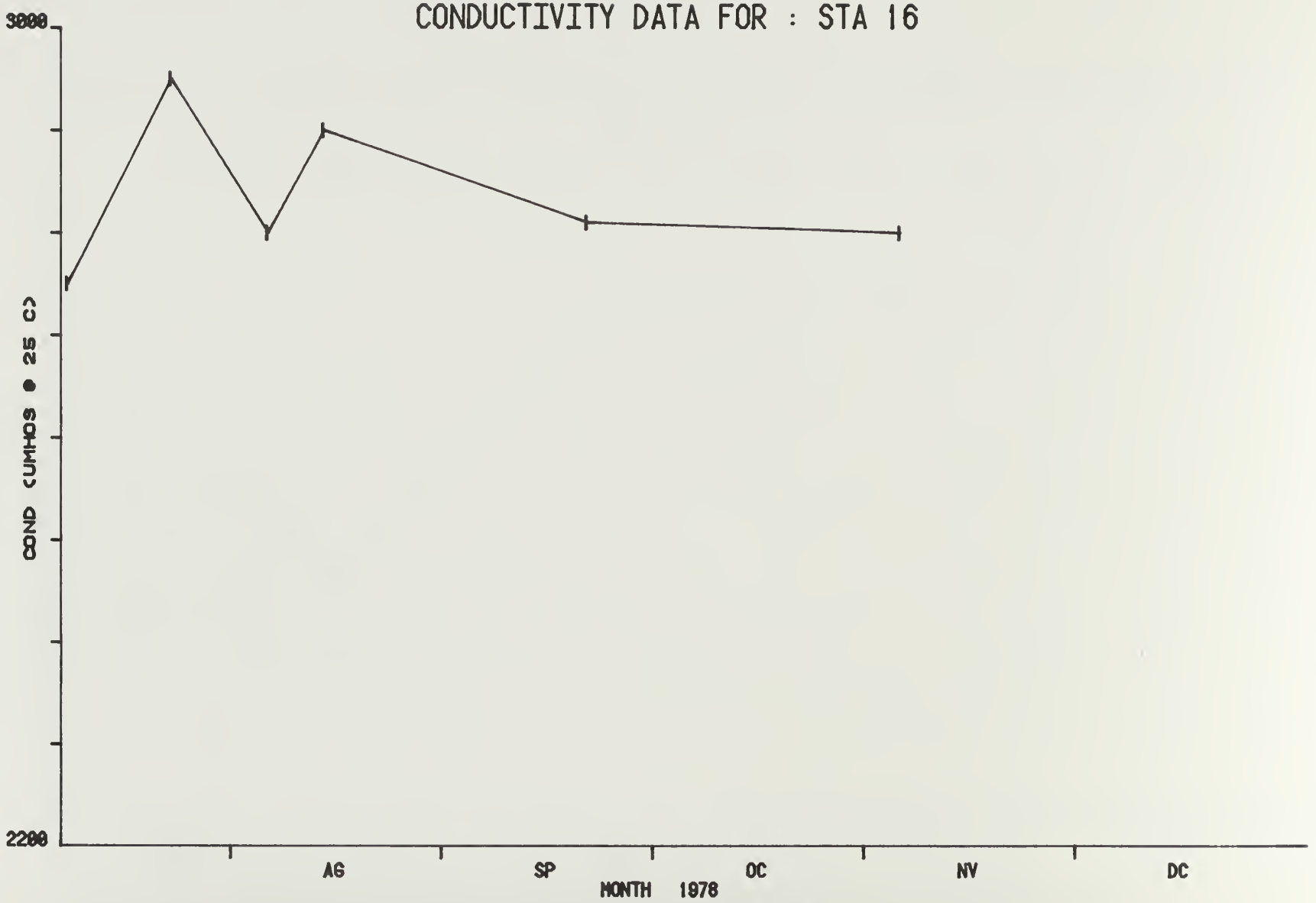


FIGURE 5-68 Conductivity Data for Surface Gaging Station No. 16, Tract C-a, August-November 1978

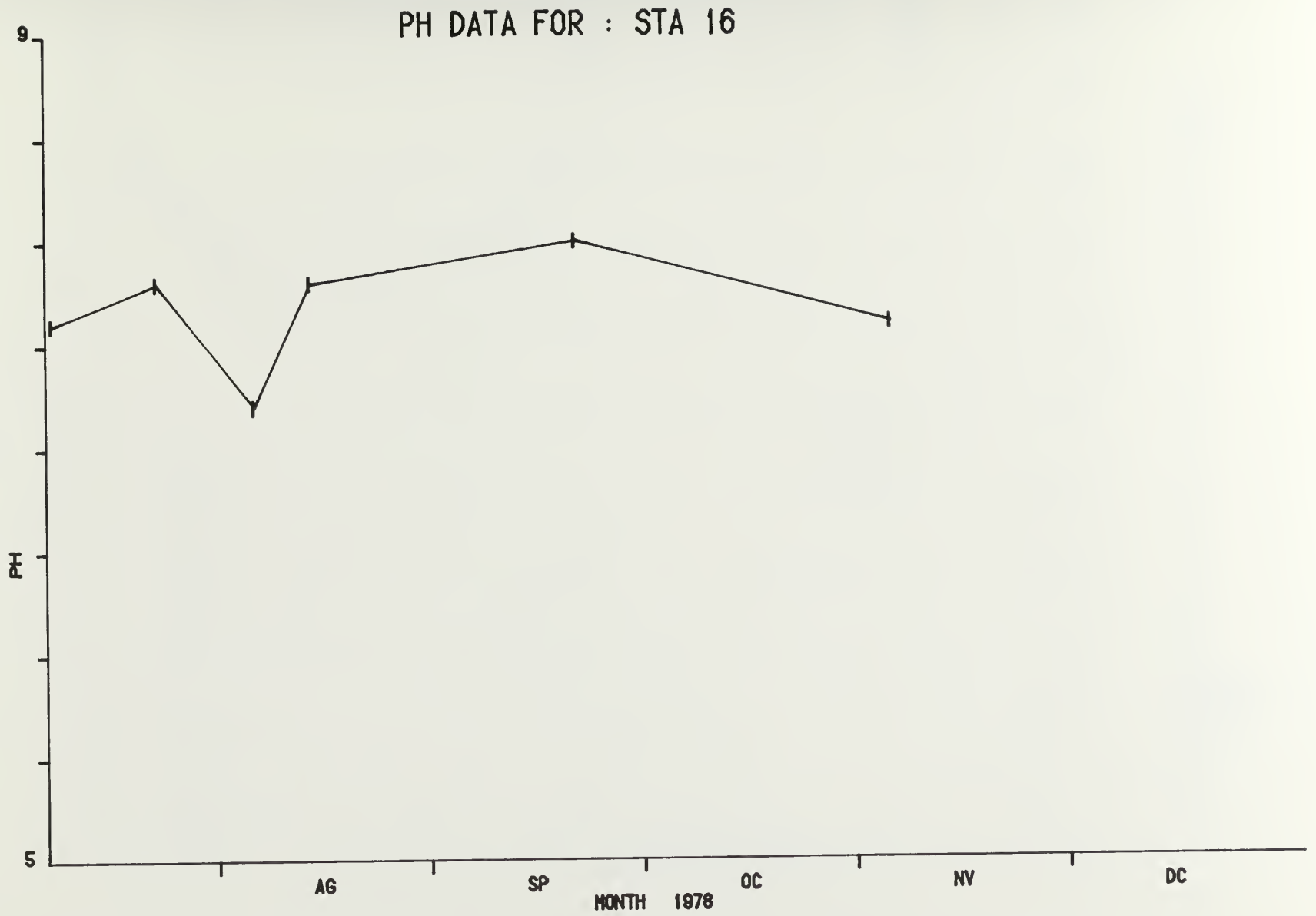


FIGURE 5-69 PH Data for Surface Gaging Station No. 16, Tract C-a, August-November 1978

TABLE 5-14 EROSION AND SEDIMENTATIONS PUMP TEST MONITORING SUMMARY

Well	1978									
	Feb 20	Mar	Apr 20	May 30	June	July	Aug	Sept	Oct	Nov
1A								X	I	
1					X	X	X	I	Destroyed	
2a	I	I	X	Destroyed						
b	I	I	X	Destroyed						
3		I	X	I	X	X	X	X	I	X
4	I	X	X	I	X	X	X	X	I	X
5	I	I	X	I	X	X	X	X	I	X
6	I				X	X	X	X	I	X
7	I	I	X	I	X	X	X	X	I	X
8	I	I			I	X	X	X	I	X
9	I	X	X	I	X	X	I	X	I	X
10	I	X	X	I	X	X	X	X	I	X
11	I	I				X	I	X	X	X
12	I	I		I		X	I	X	X	X
13	I	I		I		X	I	X	X	X
14					I	X	I	X	X	X
15	I	I		I		X	I	X	X	X
16					X	X	I	X	X	X

I = Readings taken once during month

X = Reading taken twice during month.

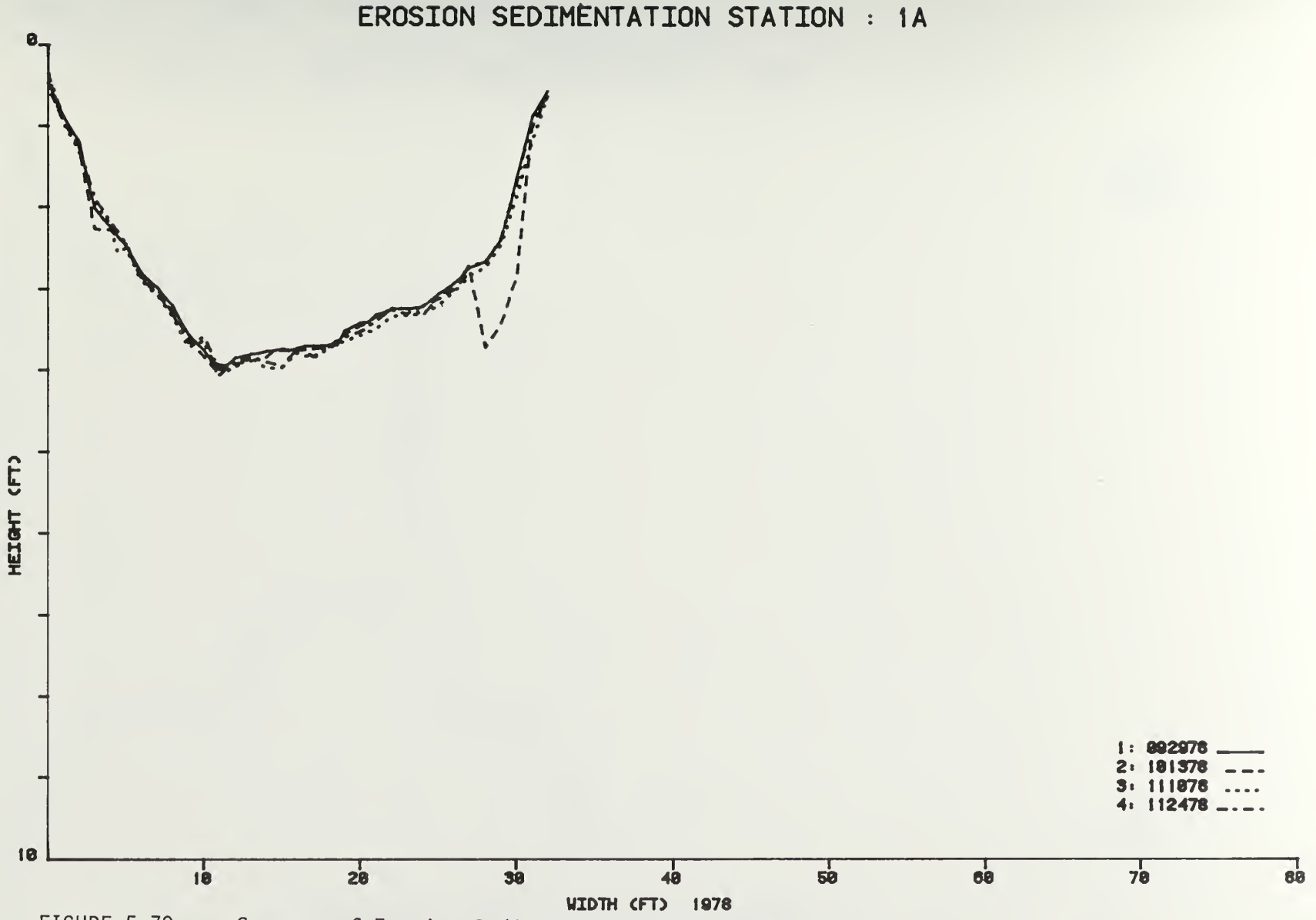


FIGURE 5-70 Summary of Erosion Sedimentation Data for Station 1A, Tract C-a, 1978

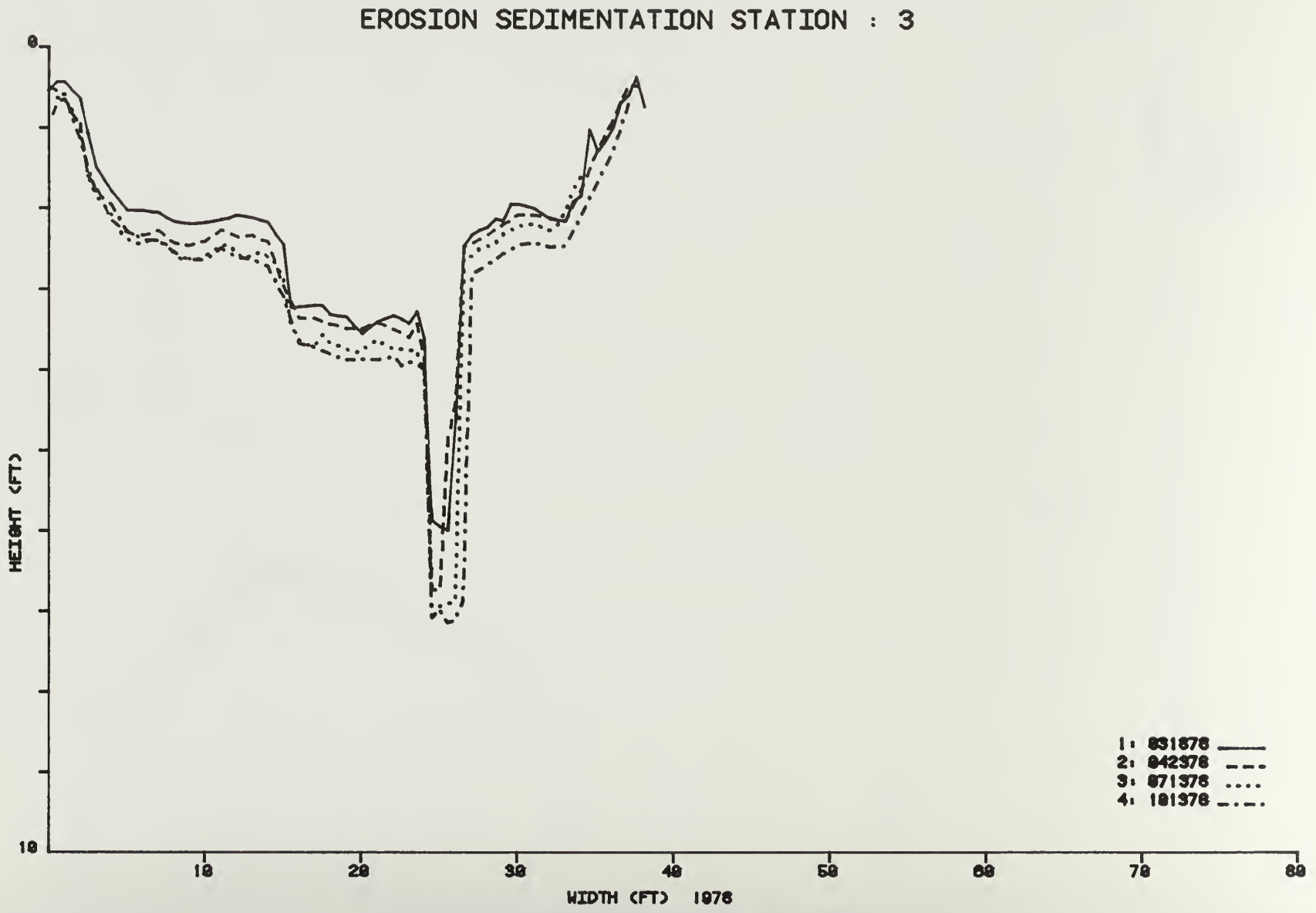


FIGURE 5-71 Summary of Erosion Sedimentation Station No. 3, Tract C-a, 1978

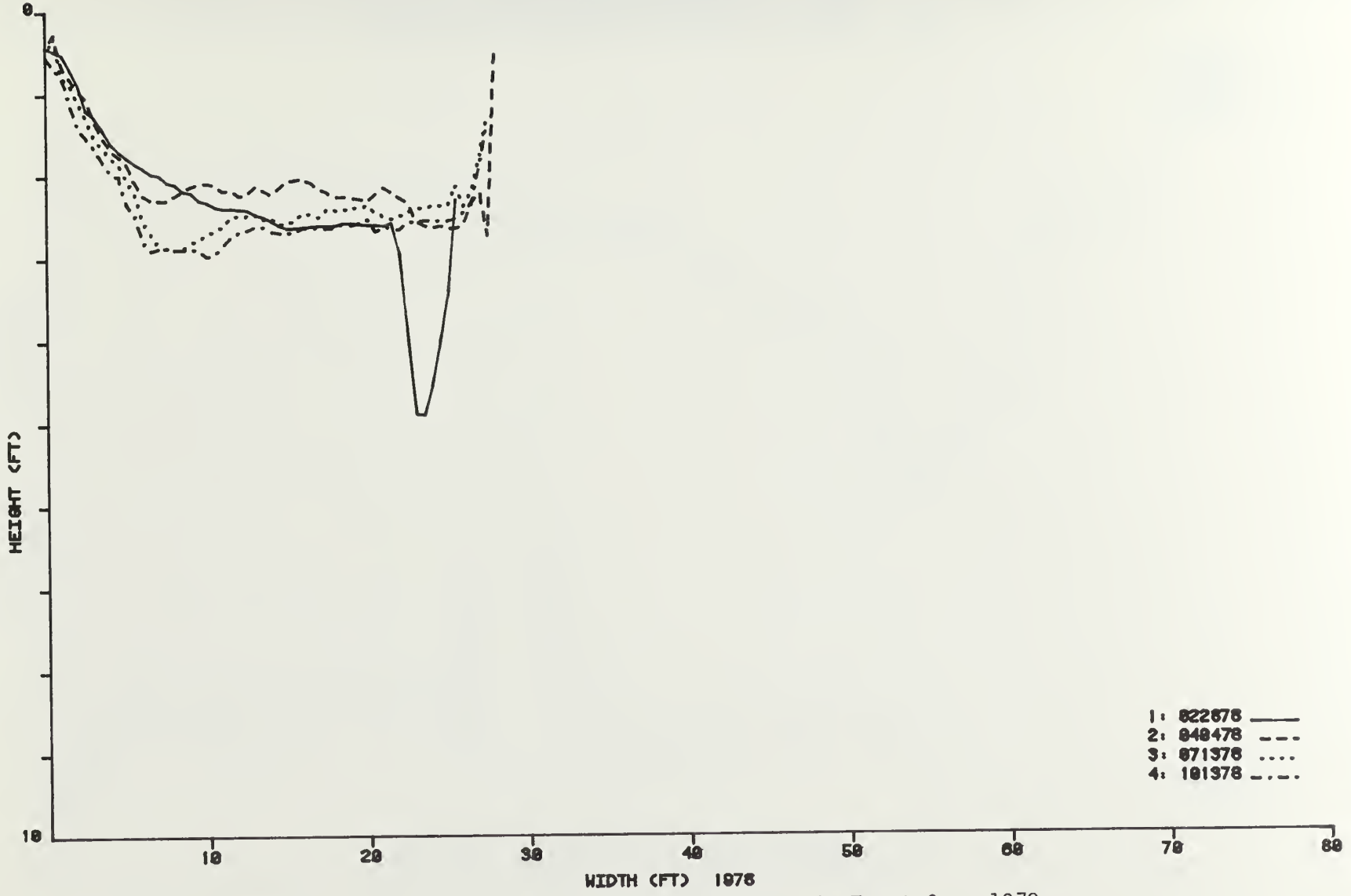


FIGURE 5-72 Summary of Erosion Sedimentation Station No. 4, Tract C-a, 1978

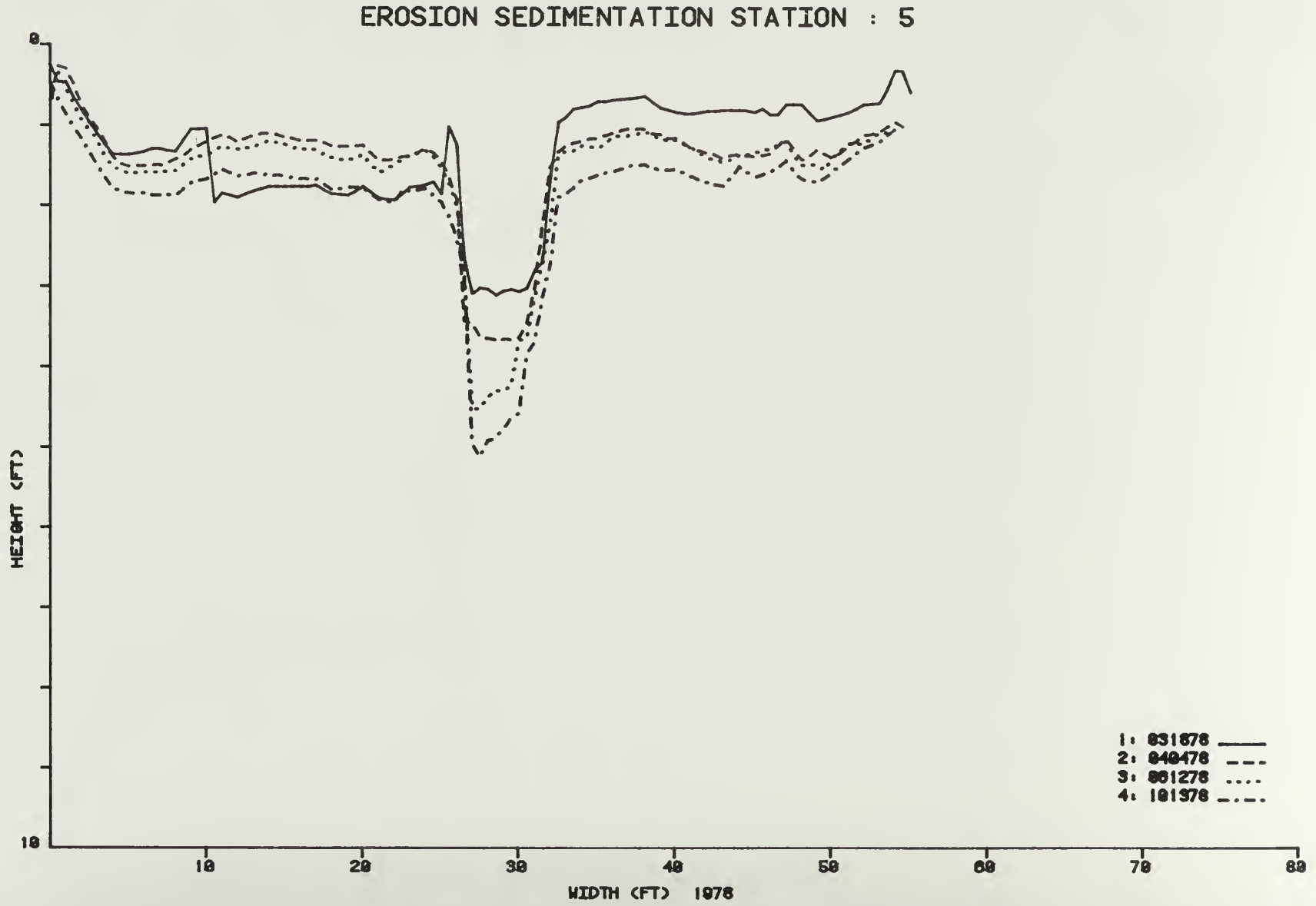


FIGURE 5-73 Summary of Erosion Sedimentation Station No. 5 Data, Tract C-a, 1978

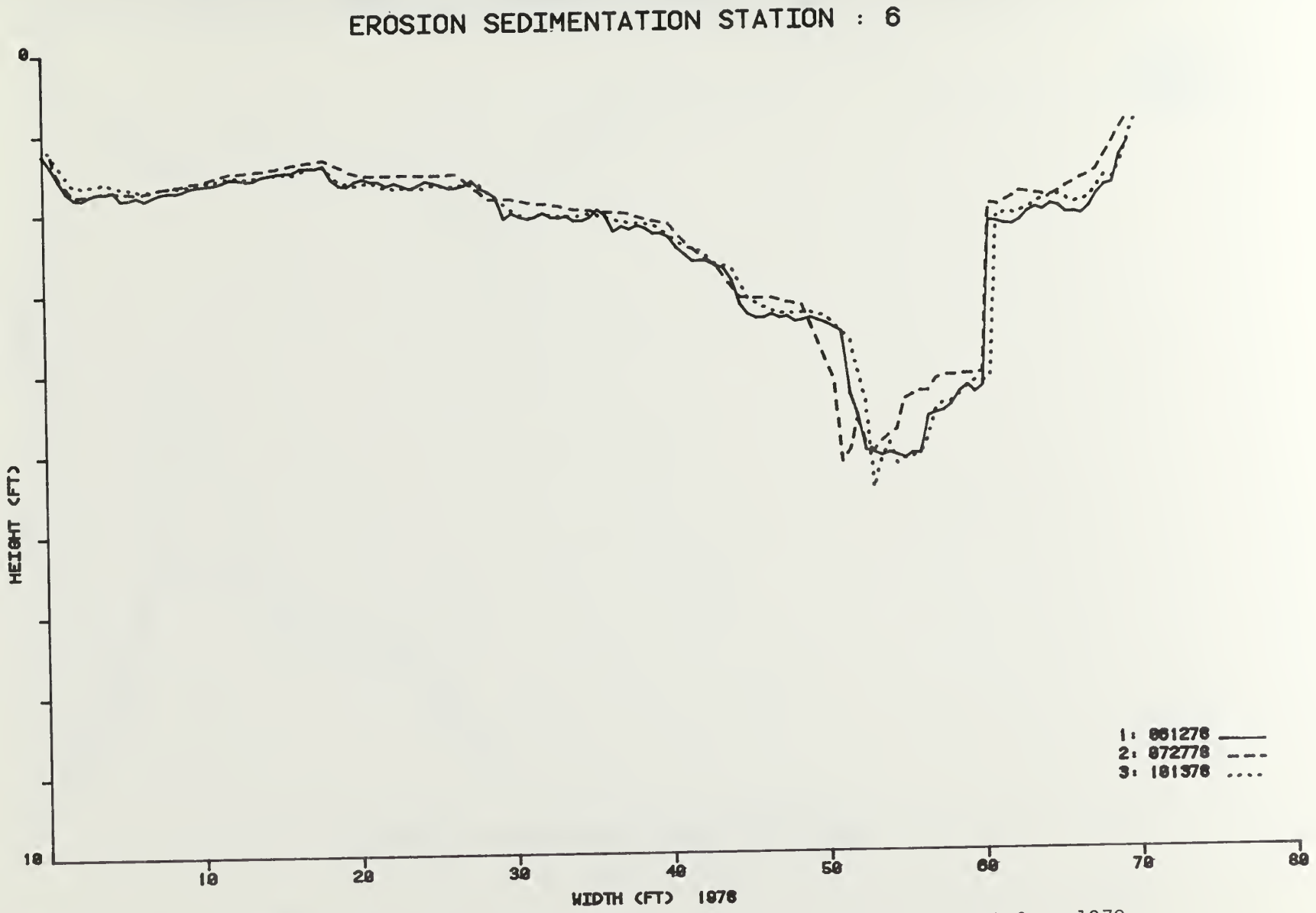


FIGURE 5-74 Summary of Erosion Sedimentation Data for Station No. 6, Tract C-a, 1978

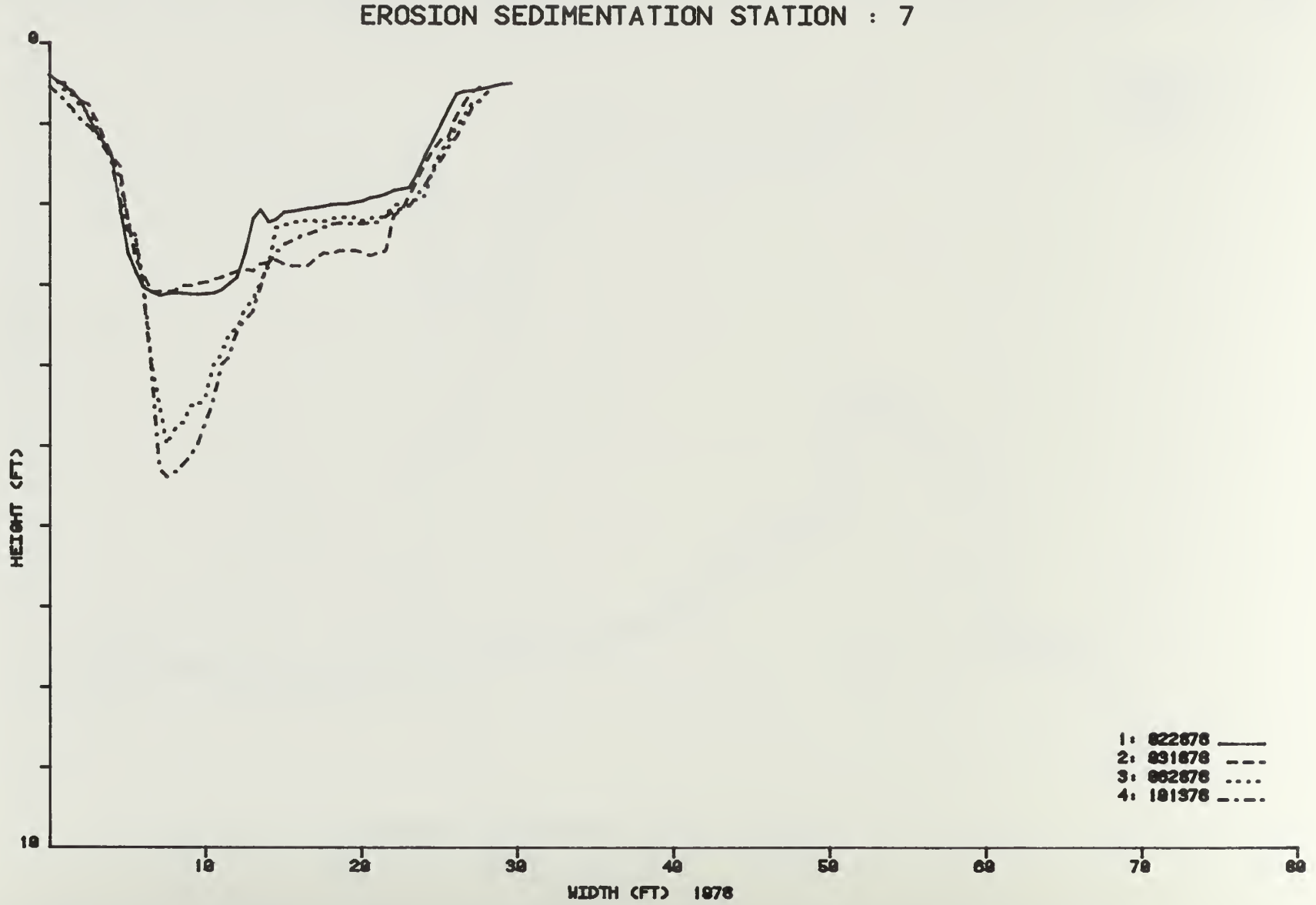


FIGURE 5-75 Summary of Erosion Sedimentation Data for Station No. 7, Tract C-a, 1978

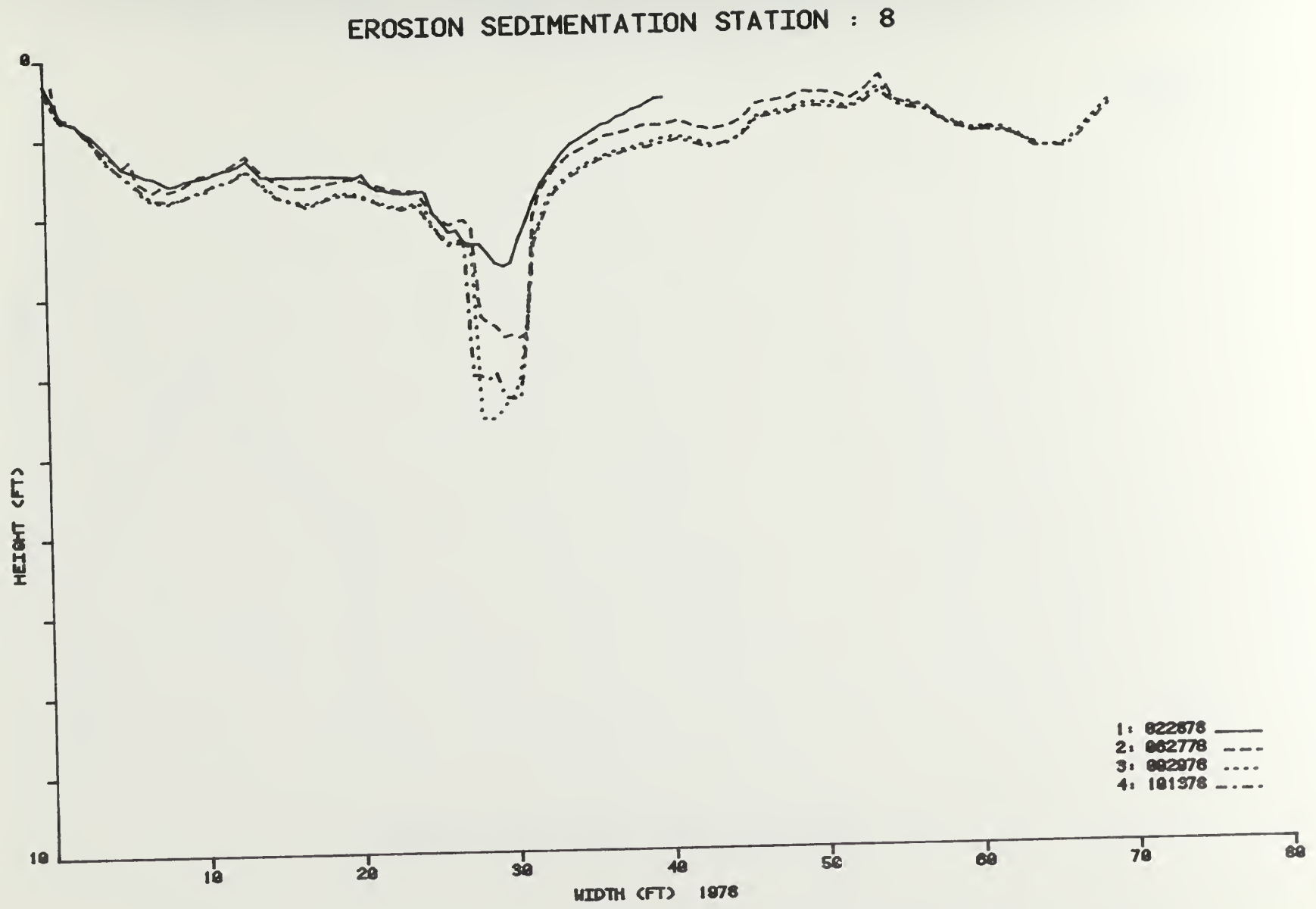


FIGURE 5-76 Summary of Erosion Sedimentation Data for Station No. 8, Tract C-a, 1978

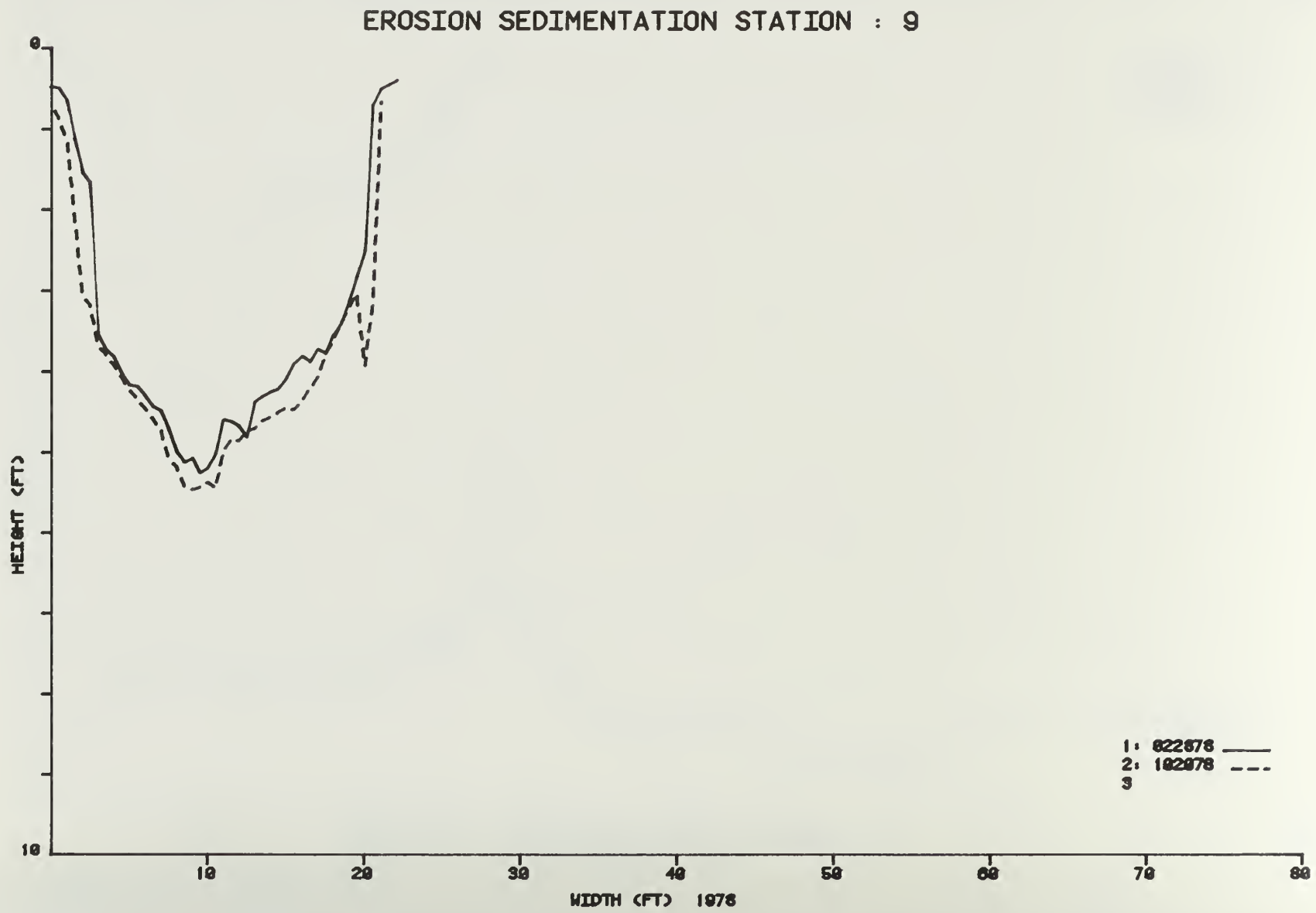


FIGURE 5-77 Summary of Erosion Sedimentation Data for Station No. 9, Tract C-a, 1978

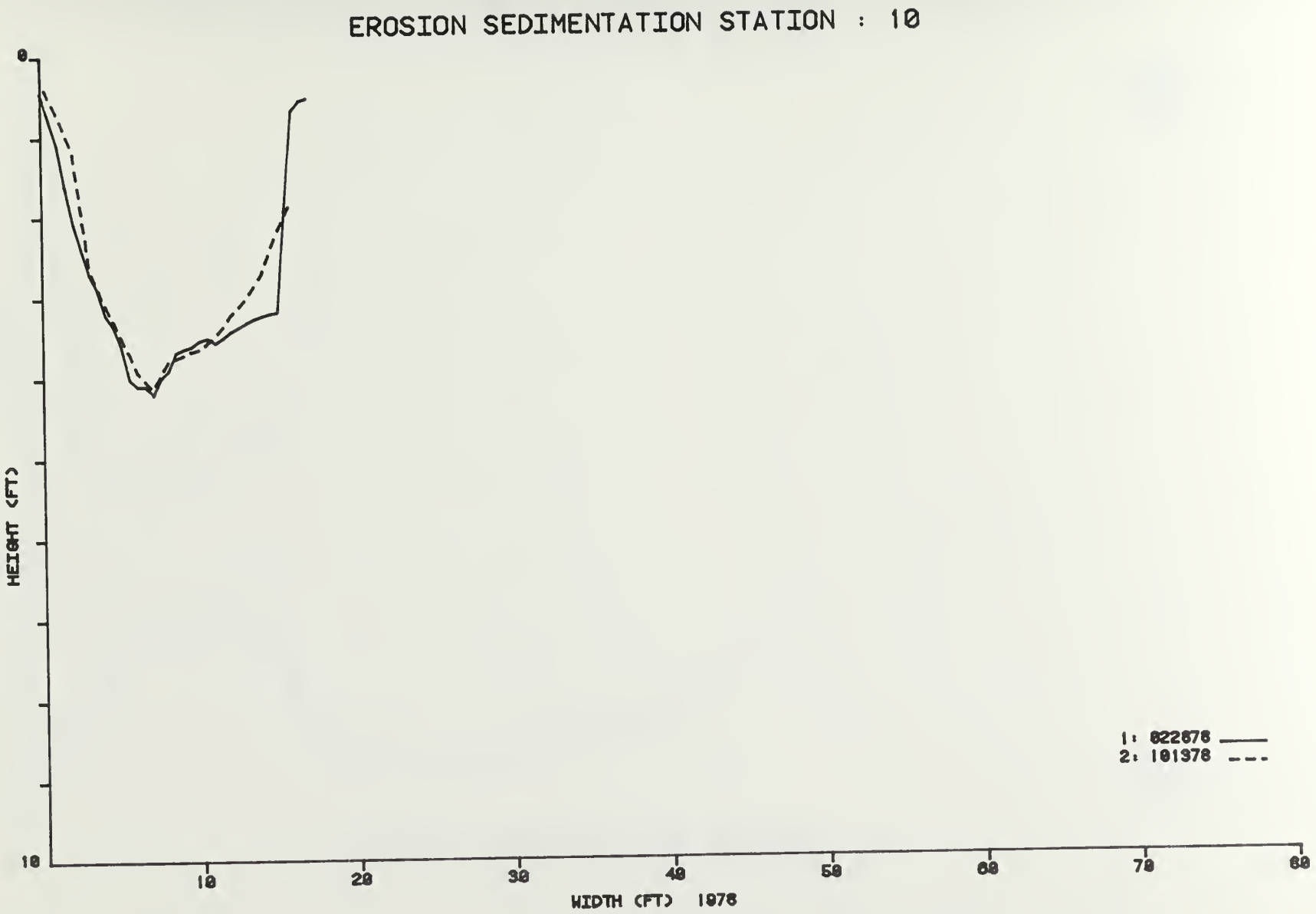


FIGURE 5-78 Summary of Erosion Sedimentation Data for Station No. 10, Tract C-a, 1978

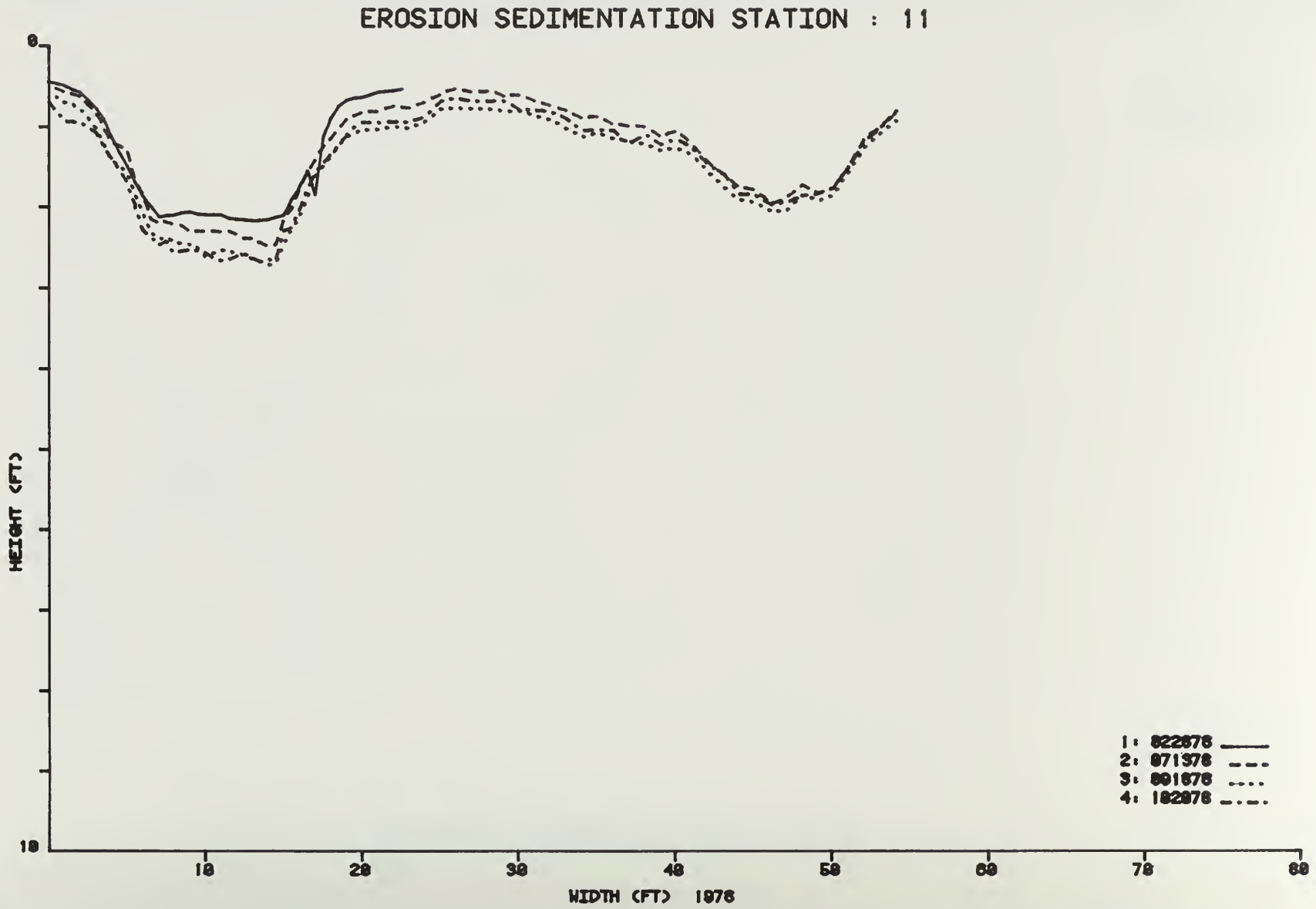


FIGURE 5-79 Summary of Erosion Sedimentation Data for Station No. 11, Tract C-a, 1978

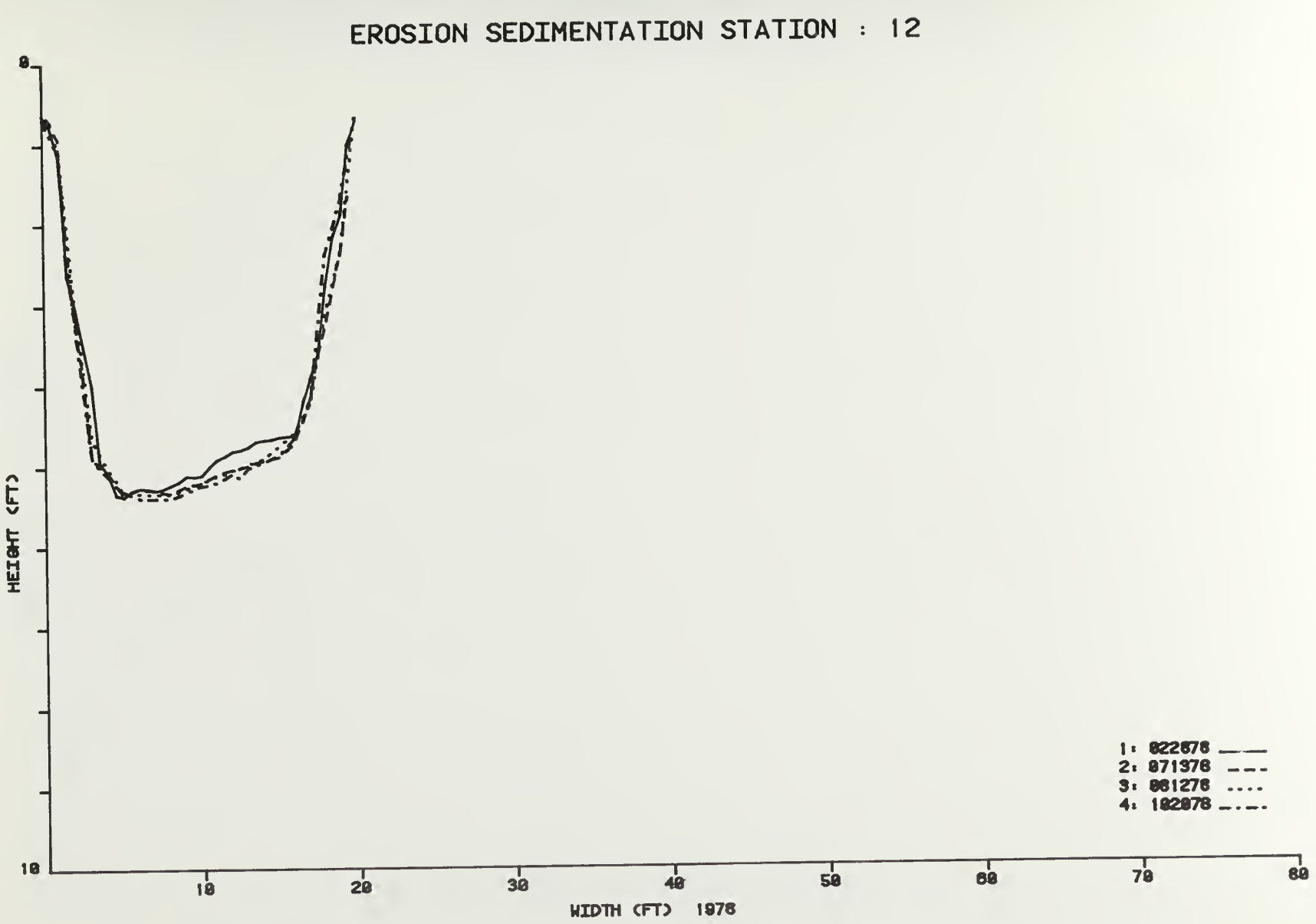


FIGURE 5-80 Summary of Erosion Sedimentation Data for Station No. 12, Tract C-a, 1978

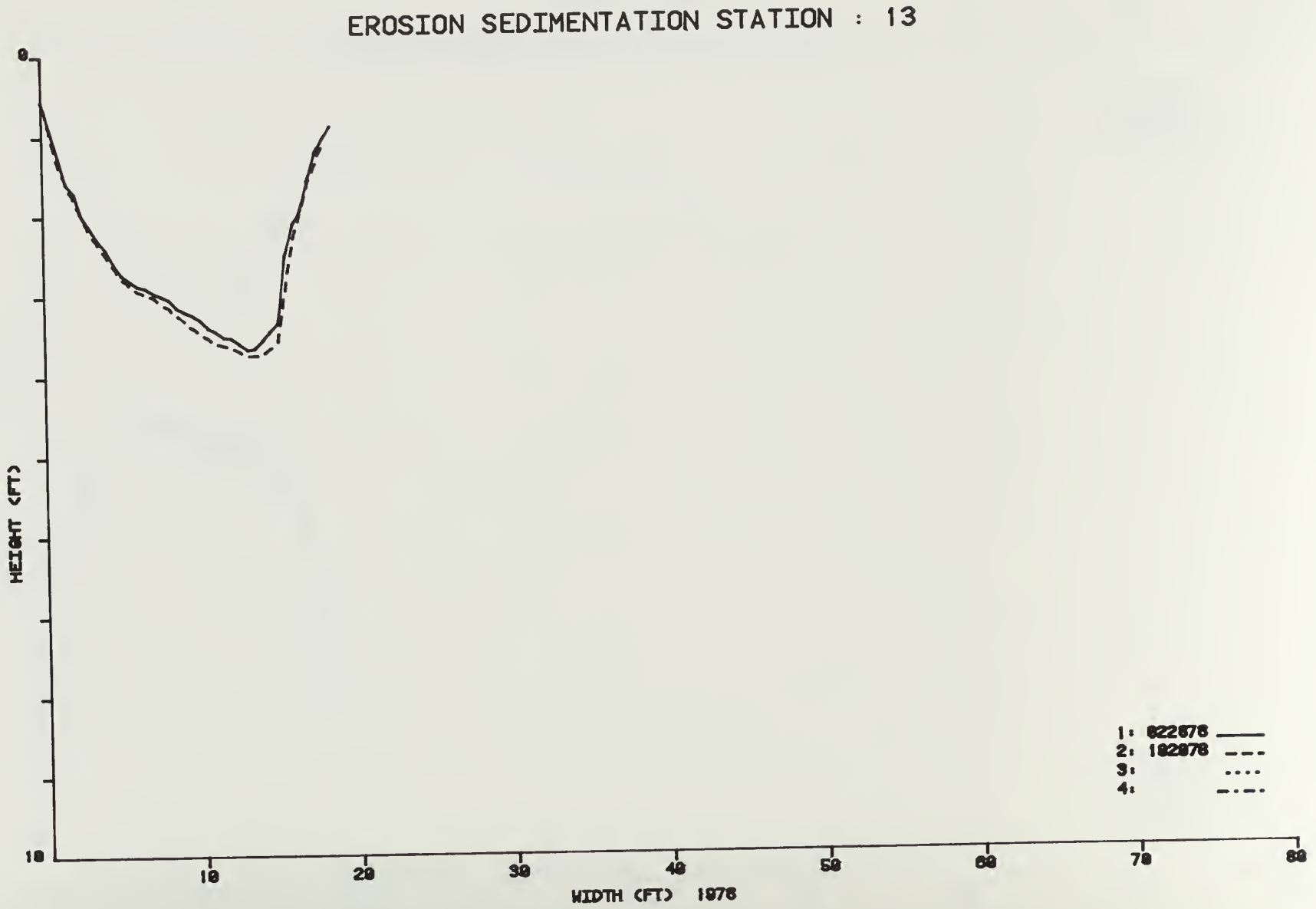


FIGURE 5-81 Summary of Erosion Sedimentation Data for Station No.13, Tract C-a, 1978

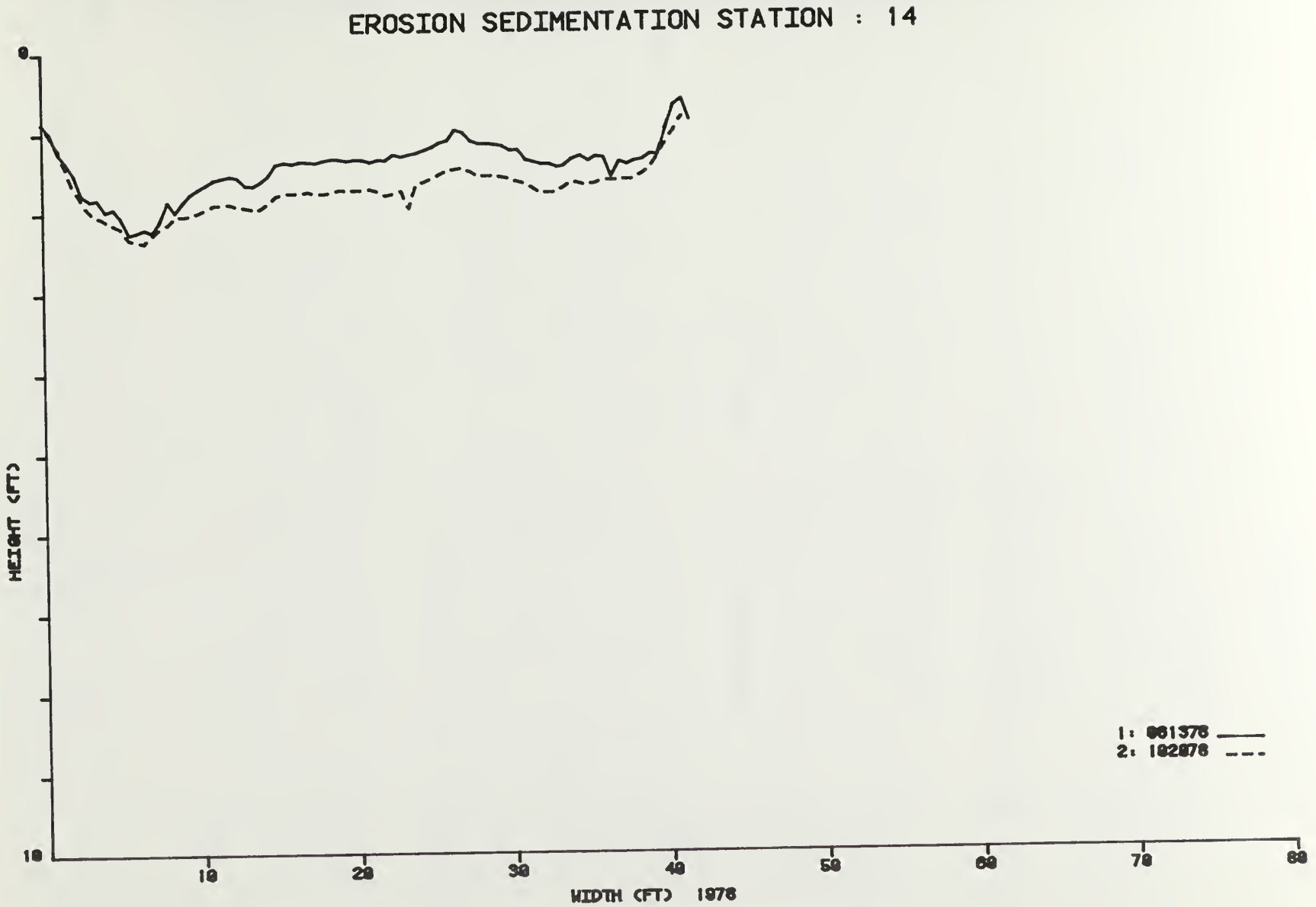


FIGURE 5-82 Summary of Erosion Sedimentation Data for Station No. 14, Tract C-a, 1978

C. Alluvial Groundwater

1. Objectives - Alluvial well holes are monitored during the pump test to determine the impact of discharge from dewatering on water level and quality in the alluvial aquifer. The program will be discontinued subject to the approval of the AOSS once the pump test program is completed.

2. Methods - The methods followed for collection of these data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion - Water level, temperature, conductivity, and pH data are shown in Figures 5-83 through 5-118 for G-S S11A shallow, G-S S11A, G-S S24, G-S S26, G-S S27A, G-S S28A, G-S S29 and G-S S29A deep holes. Table 5-14 summarizes the MDP pump test for alluvial wells. In addition, water level data were collected from G-S S28 shallow. The water level at this hole was not high enough to allow a sample to be collected.

The hydrograph for G-S S11A deep indicates that a sharp rise in water level occurred in May 1978. This rise in water level, both in the deep and shallow sections of this hole, are the result of the monitoring holes being inundated by the combined effects of the dewatering discharge and spring snowmelt run-off. It is felt therefore, that these rises are not indicative of what happened in the aquifer, and, in fact, the data collected from June through November support this argument.

Conductivity values for G-S S11A dropped sharply between March and May to approximately 1,200 micromhos per centimeter at 25°C. The data collected through June were probably affected by the May inundation and are not representative of the aquifer. Since July 1978 the conductivity has generally risen and compares quite favorably with the conductivity data collected from G-S S11.

As already stated, the water level data for G-S S11A shallow were affected by inundation in May. Toward the end of May, the hole dried up and has not contained water since that time.

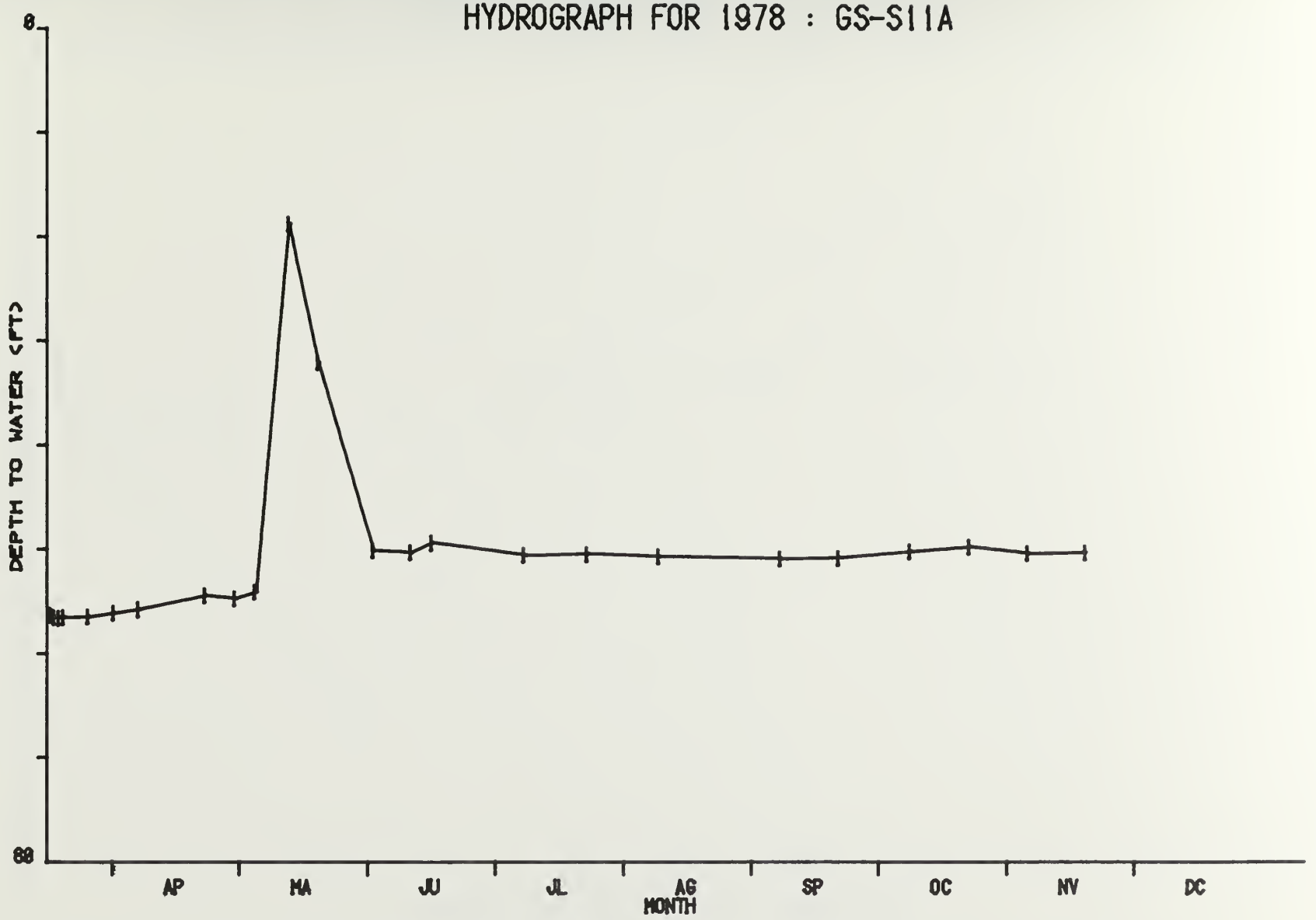


FIGURE 5-83 Water Level Hydrograph for Alluvial Hole G-S S11A Deep, Tract C-a, 1978

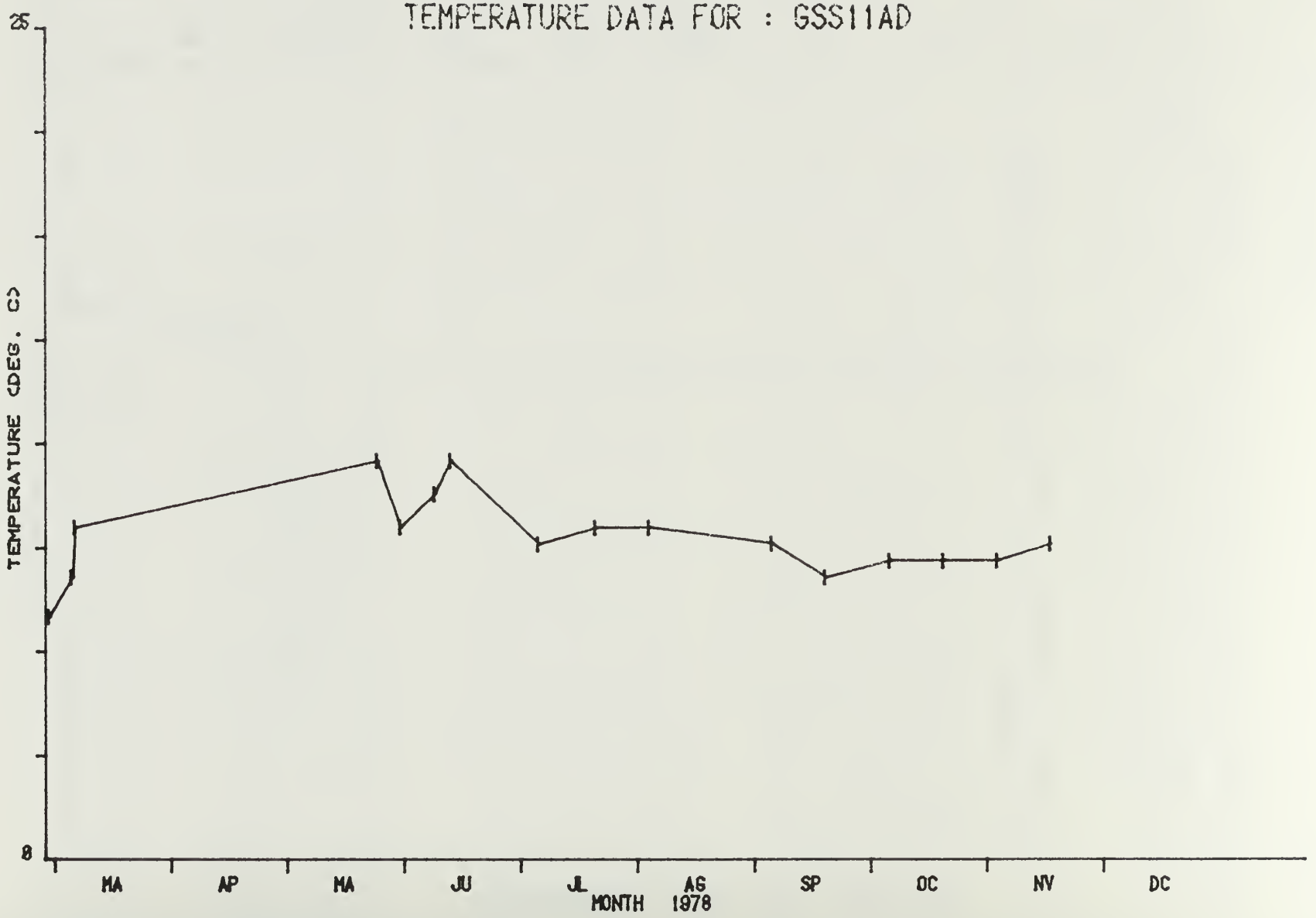


FIGURE 5-84 Temperature Hydrograph for Alluvial Hole G-S S11A Deep, Tract C-a, 1978

FIGURE 5-85 Conductivity Hydrograph for Alluvial Hole G-S S11A Deep, Tract C-a, 1978

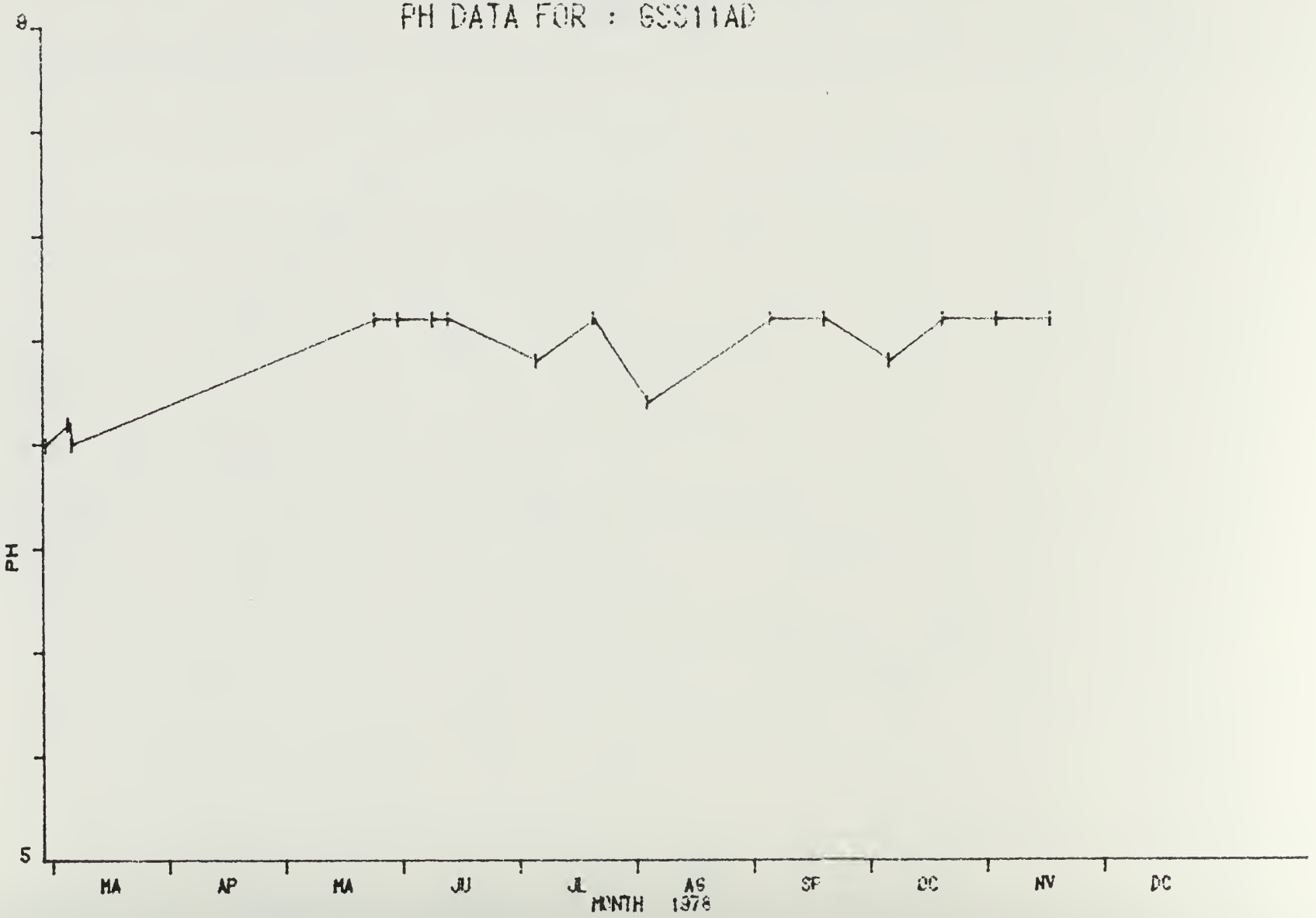
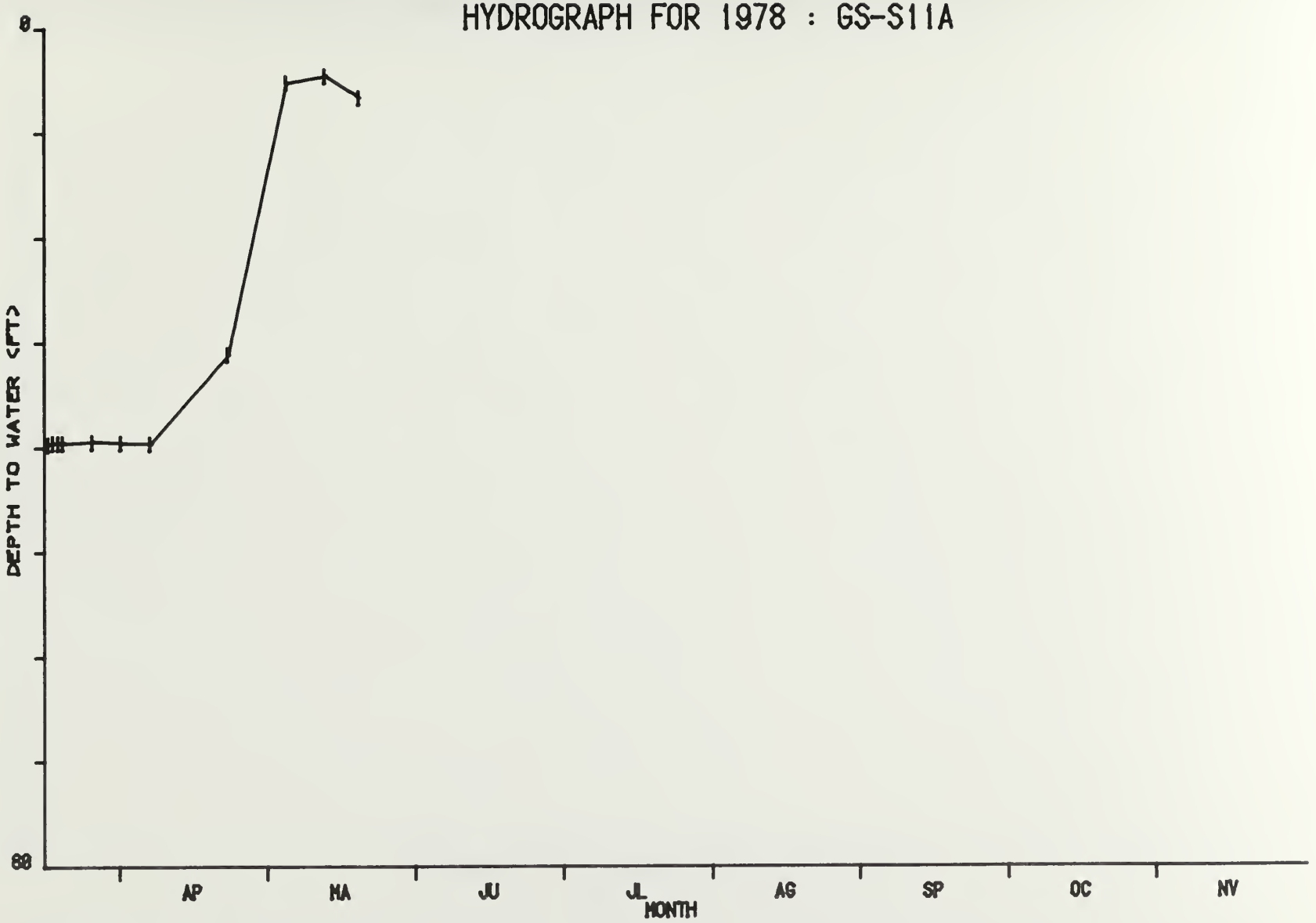


FIGURE 5-86 PH Hydrograph for Alluvial Hole G-S S11A Deep, Tract C-a, 1978



FIGUR E 5-87 Water Level Hydrograph for Alluvial Hole G-S S11A Shallow, Tract C-a, 1978

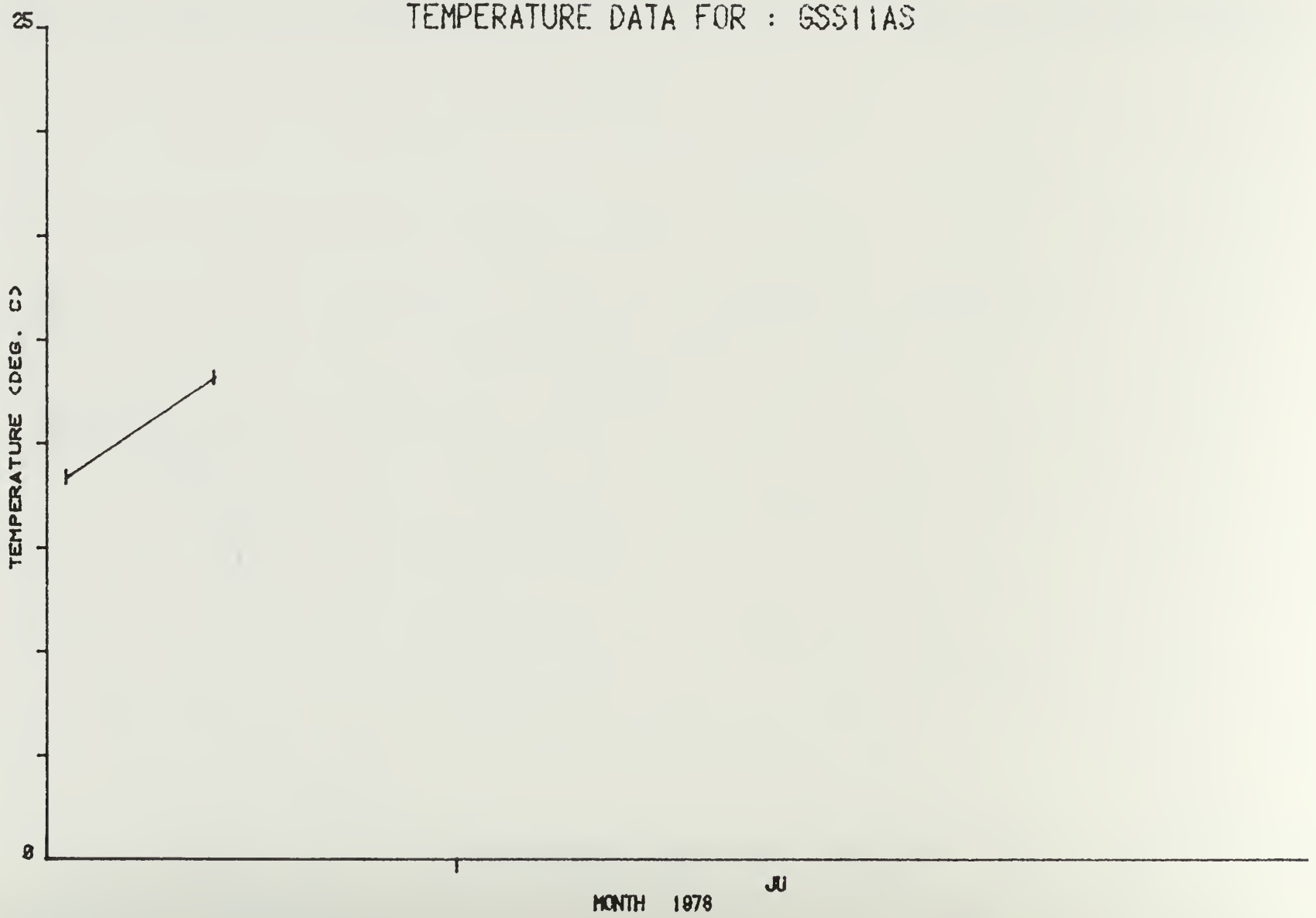


FIGURE 5-88 Temperature Data Hydrograph for Alluvial Hole G-S S11A Shallow, Tract C-a, 1978

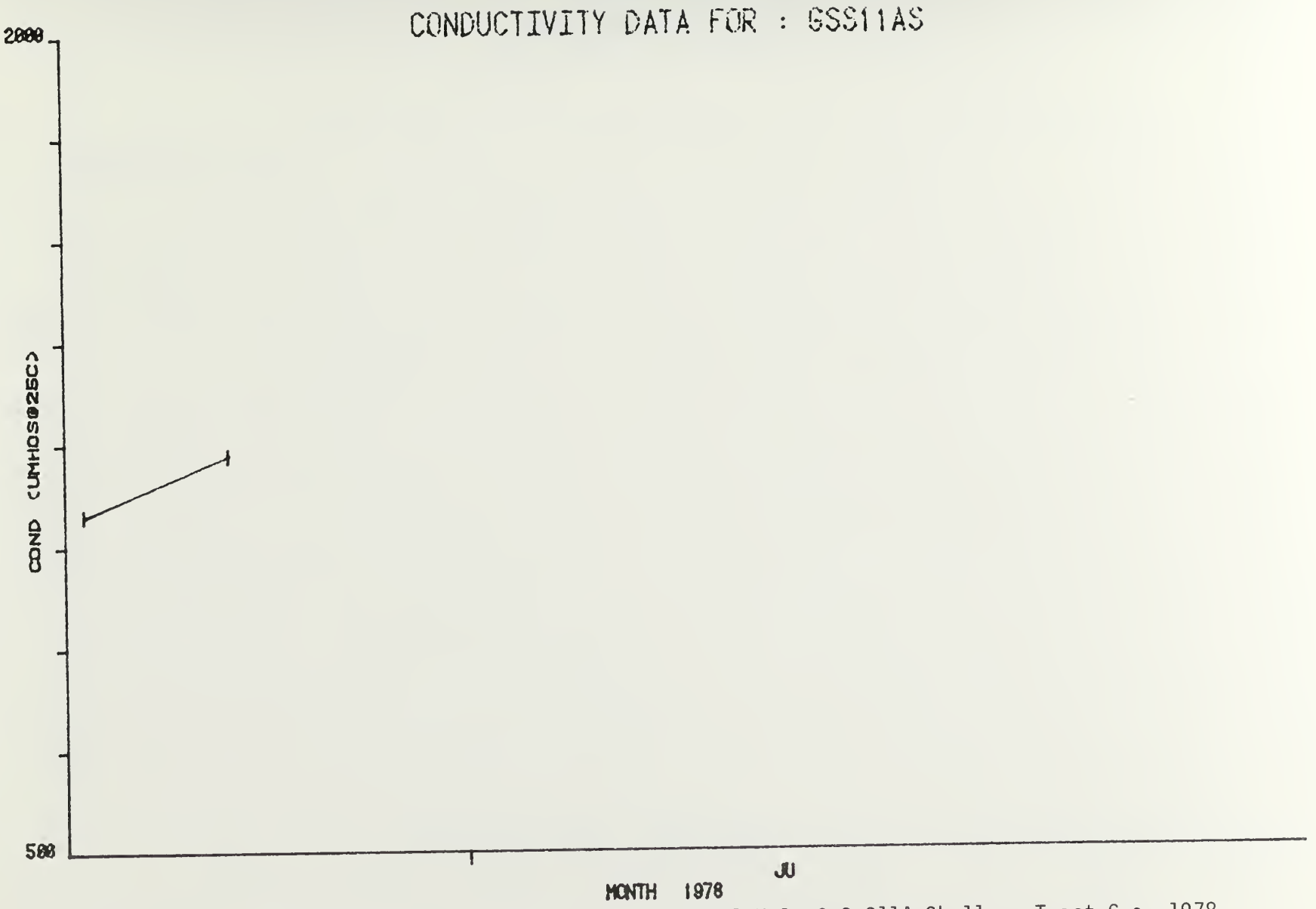


FIGURE 5-89 Conductivity Data Hydrograph for Alluvial Hole G-S S11A Shallow, Tract C-a, 1978

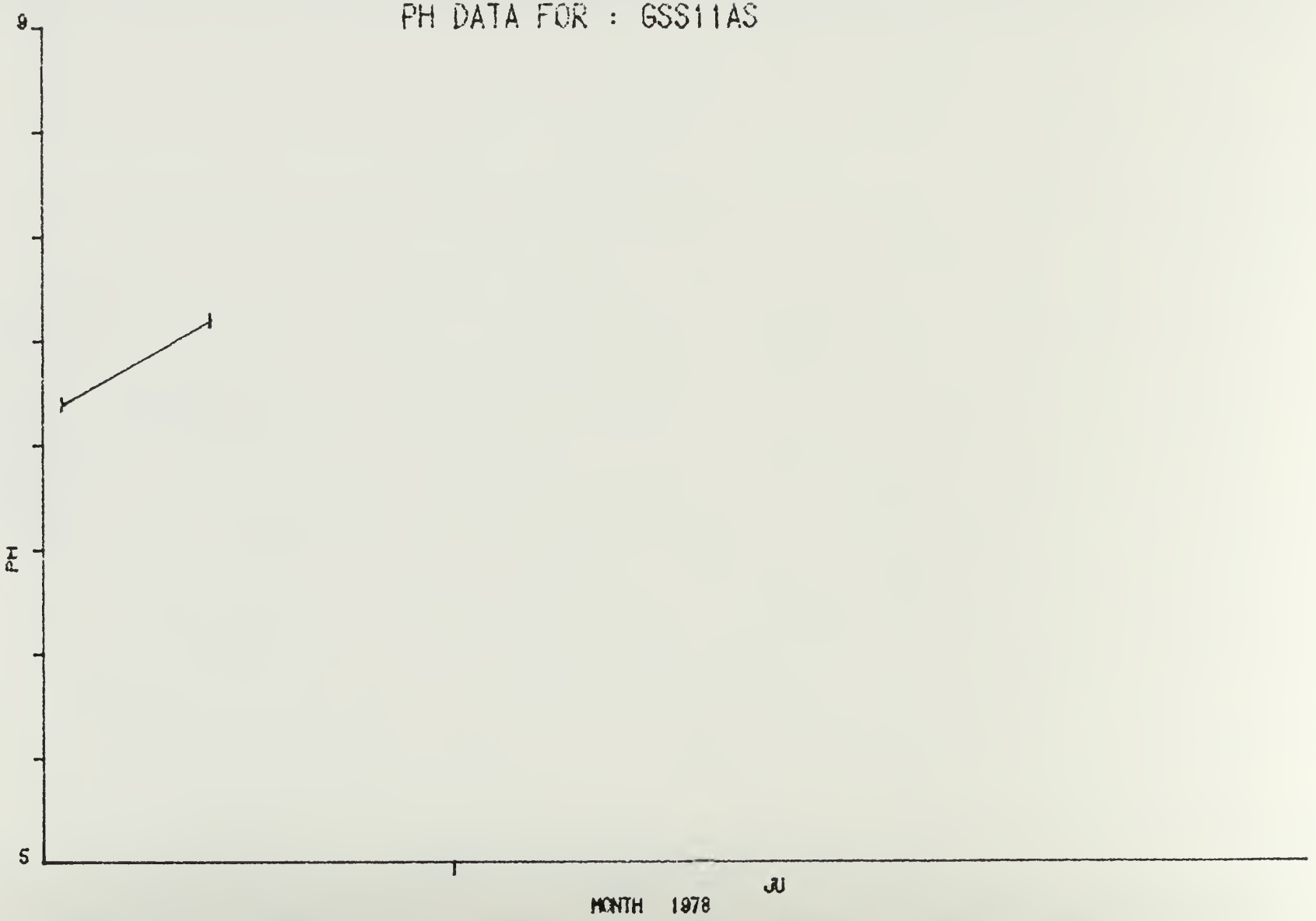


FIGURE 5-90 PH Data Hydrograph for Alluvial Hole G-S S11A Shallow, Tract C-a, 1978

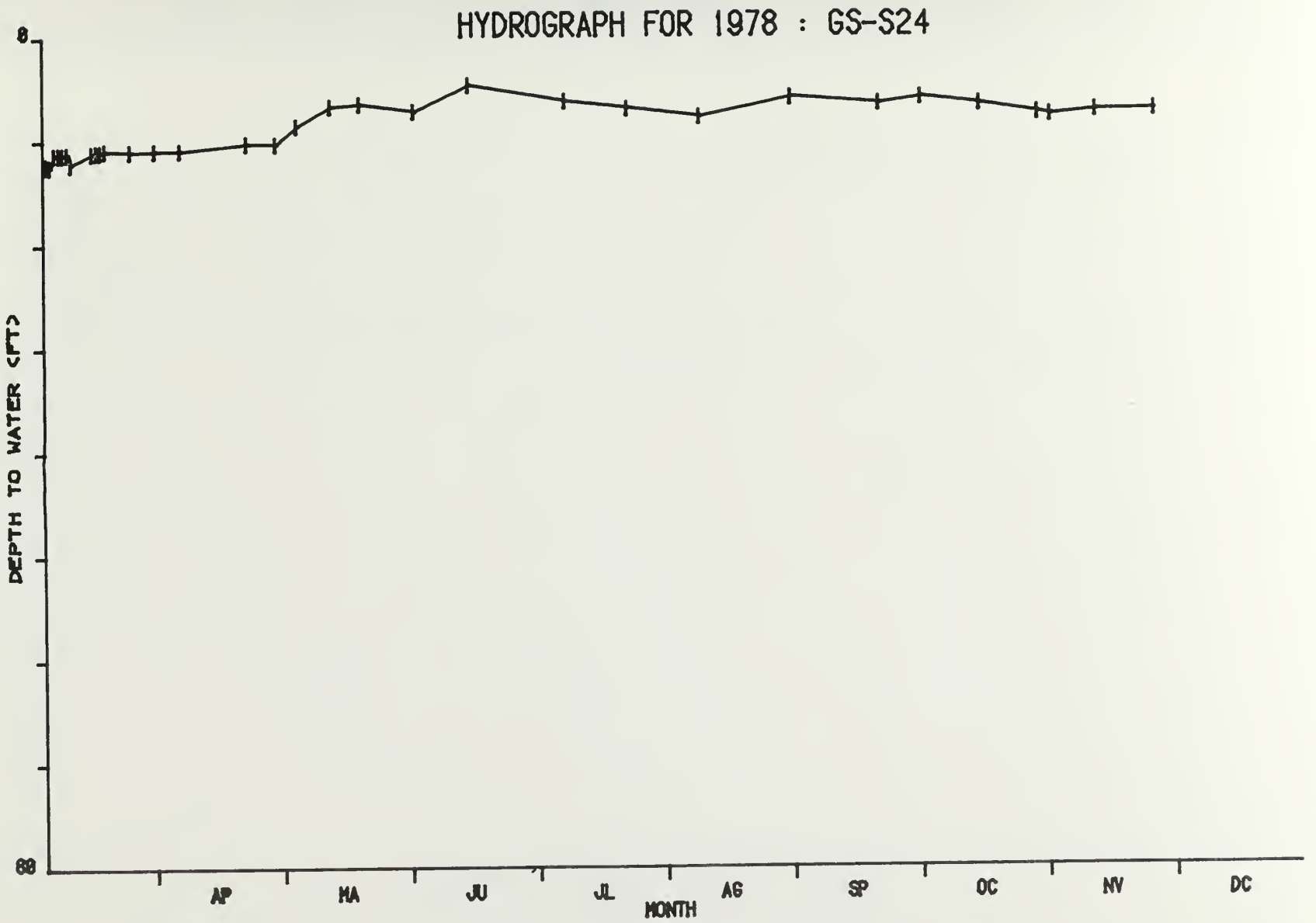


FIGURE 5-91 Water Level Hydrograph Data for Alluvial Hole G-S S24, Tract C-a, 1978

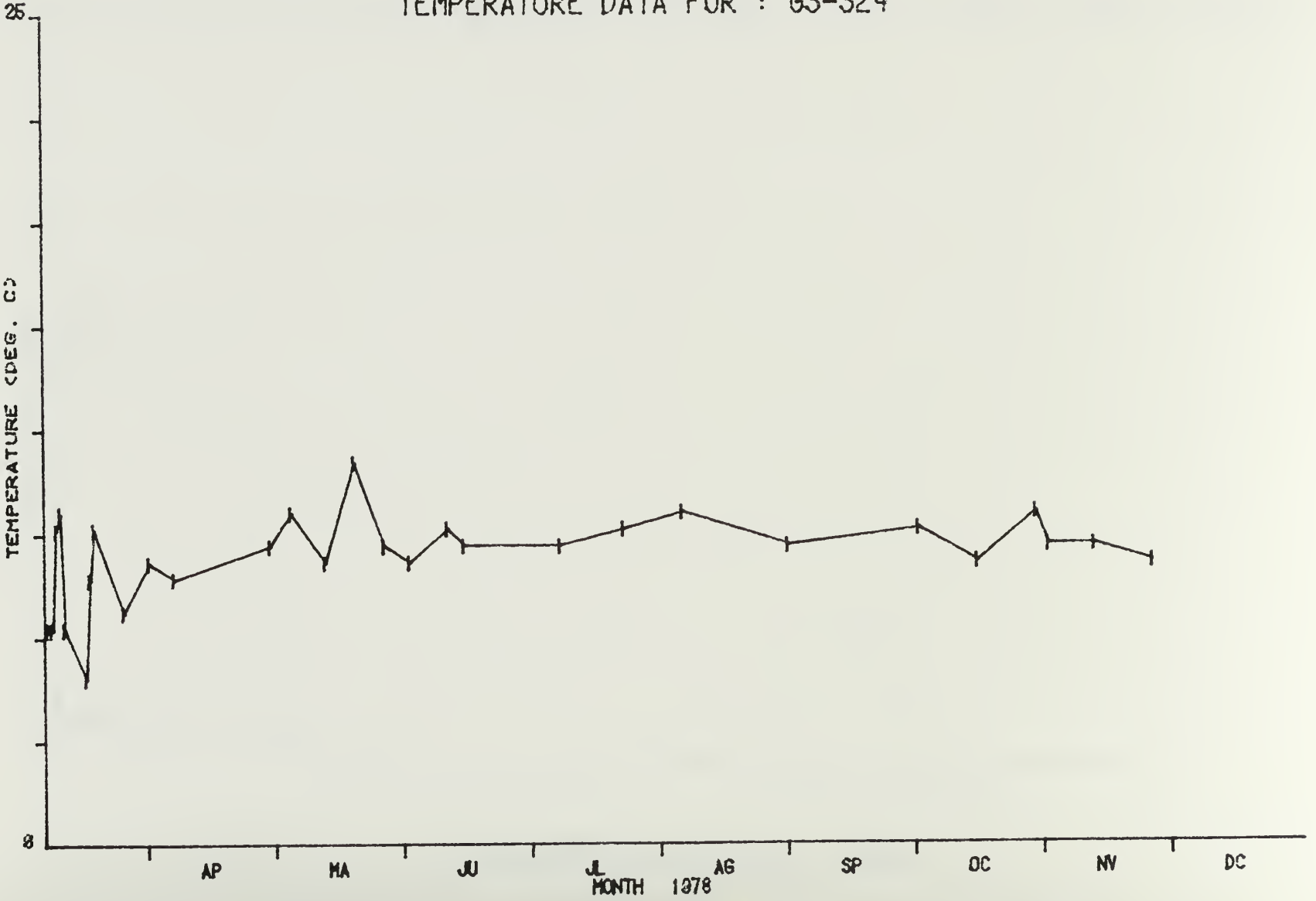


FIGURE 5-92 Temperature Data Hydrograph for Alluvial Hole G-S S24, Tract C-a, 1978

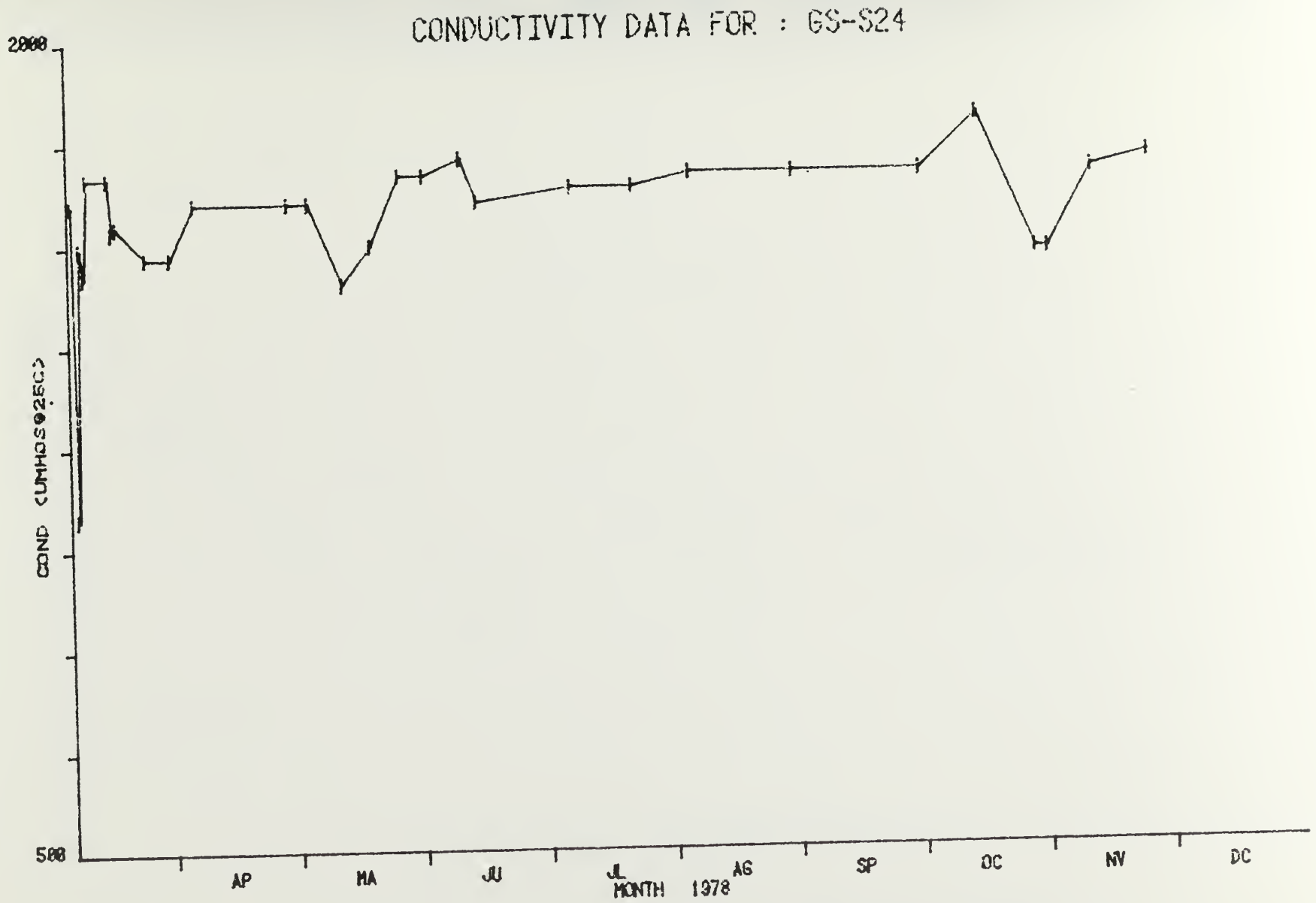


FIGURE 5-93 Conductivity Data Hydrograph for Alluvial Hole G-S S24, Tract C-a, 1978

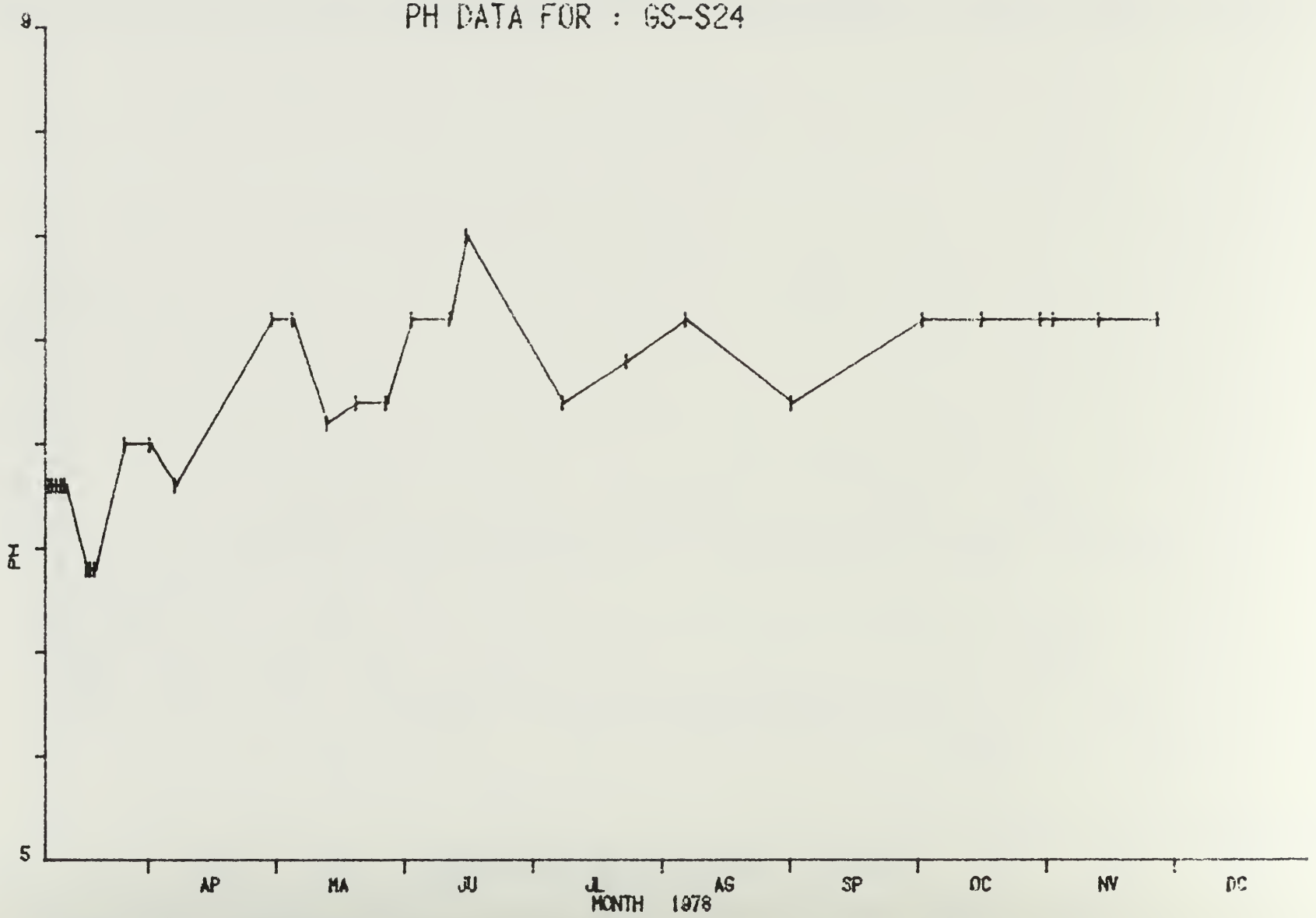


FIGURE 5-94 PH Data Hydrograph for Alluvial Hole G-S S24, Tract C-a, 1978

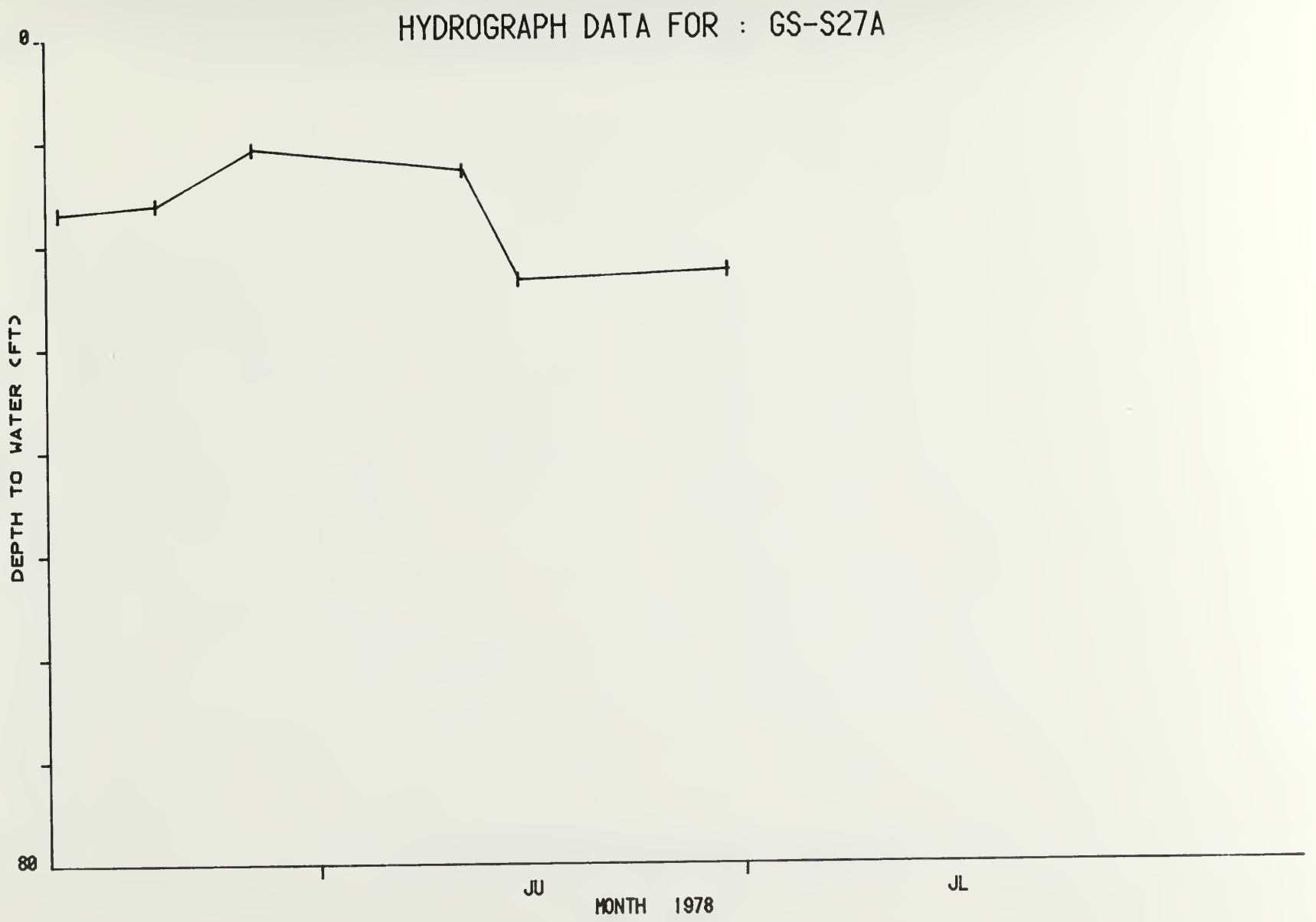


FIGURE 5-95 Water Level Hydrograph for Alluvial Hole G-S S27A, Tract C-a, 1978

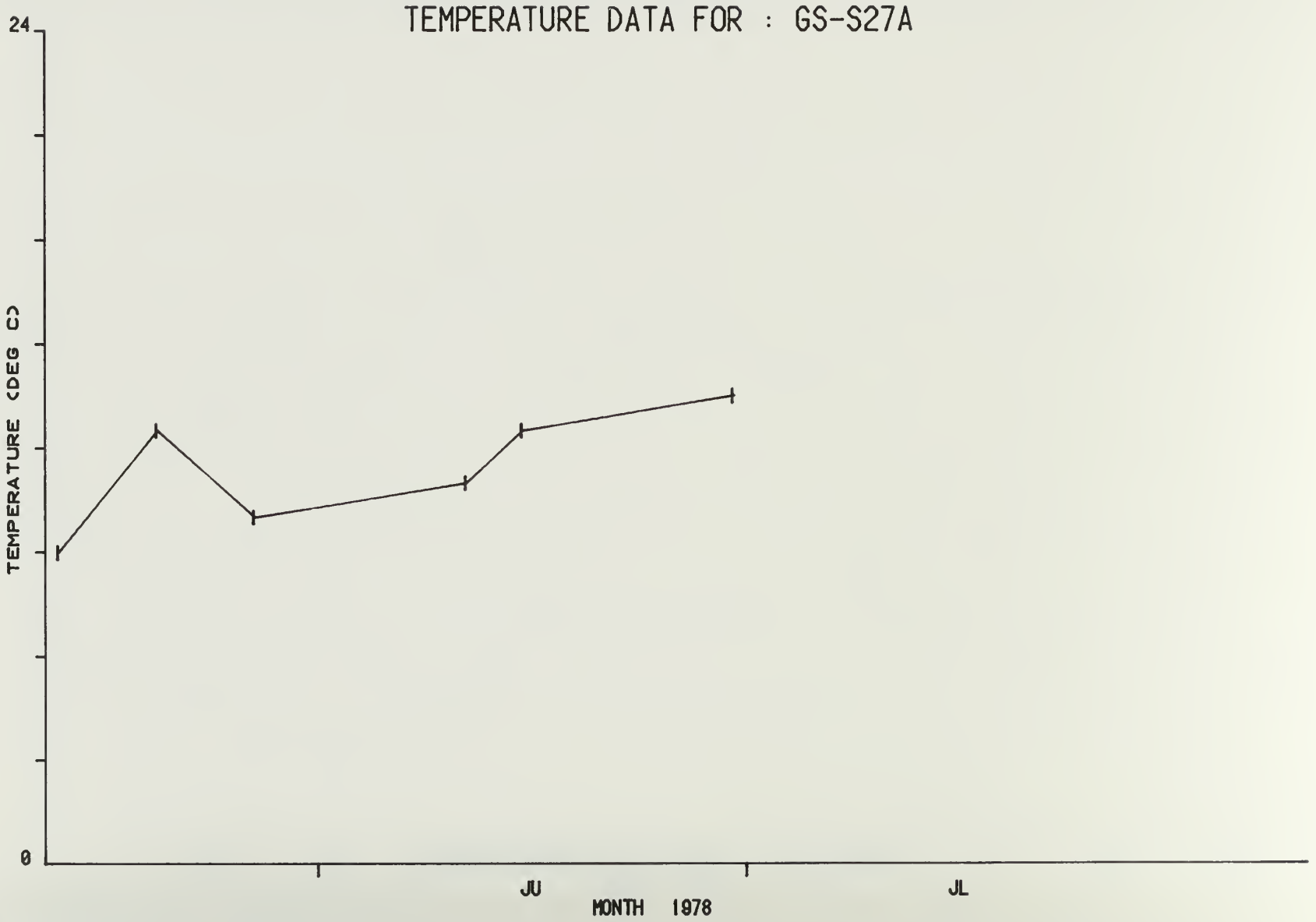


FIGURE 5-96 Temperature Data Hydrograph for Alluvial Hole G-S S27A, Tract C-a, 1978

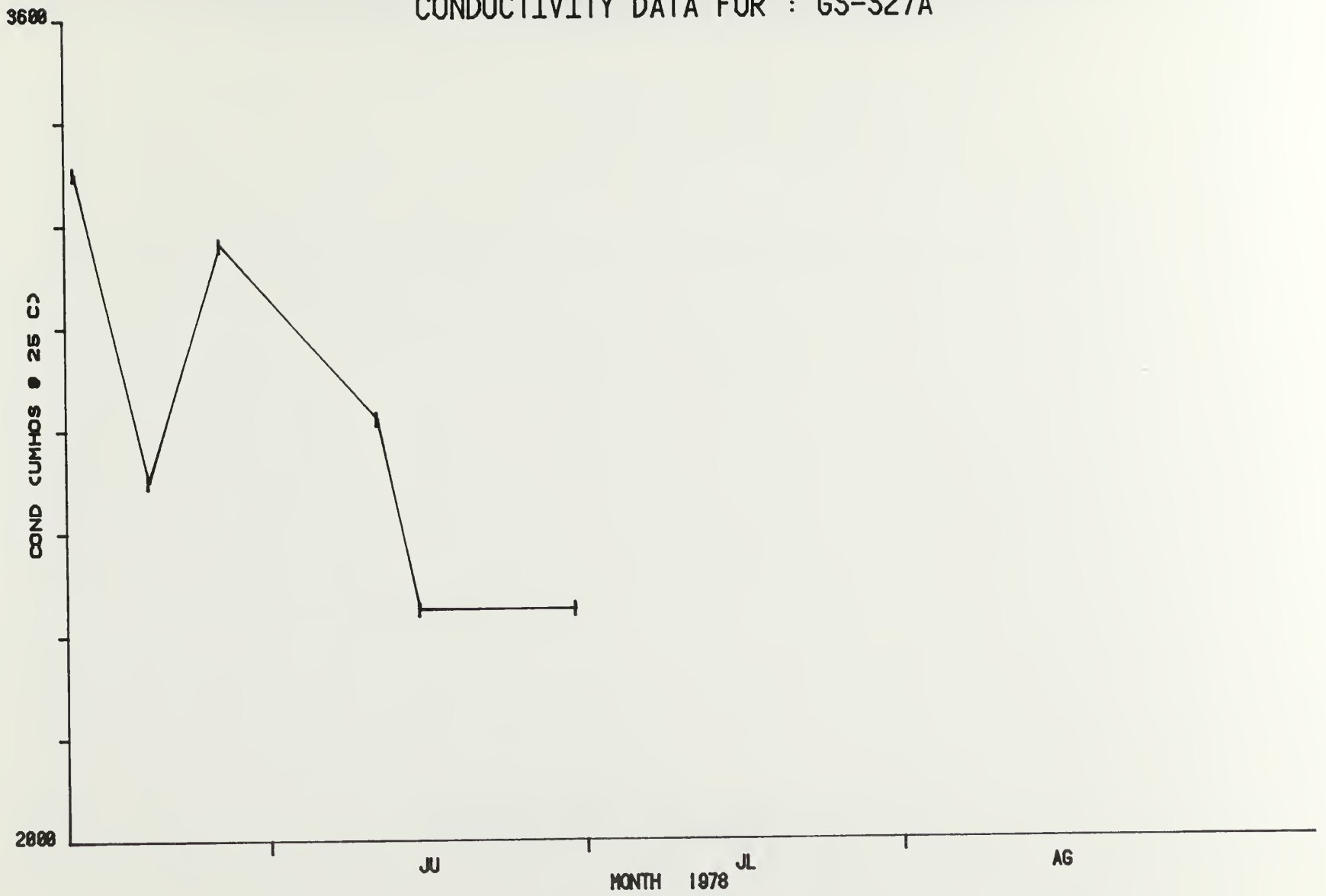


FIGURE 5-97 Conductivity Data Hydrograph for Alluvial Hole G-S S27A, Tract C-a, 1978

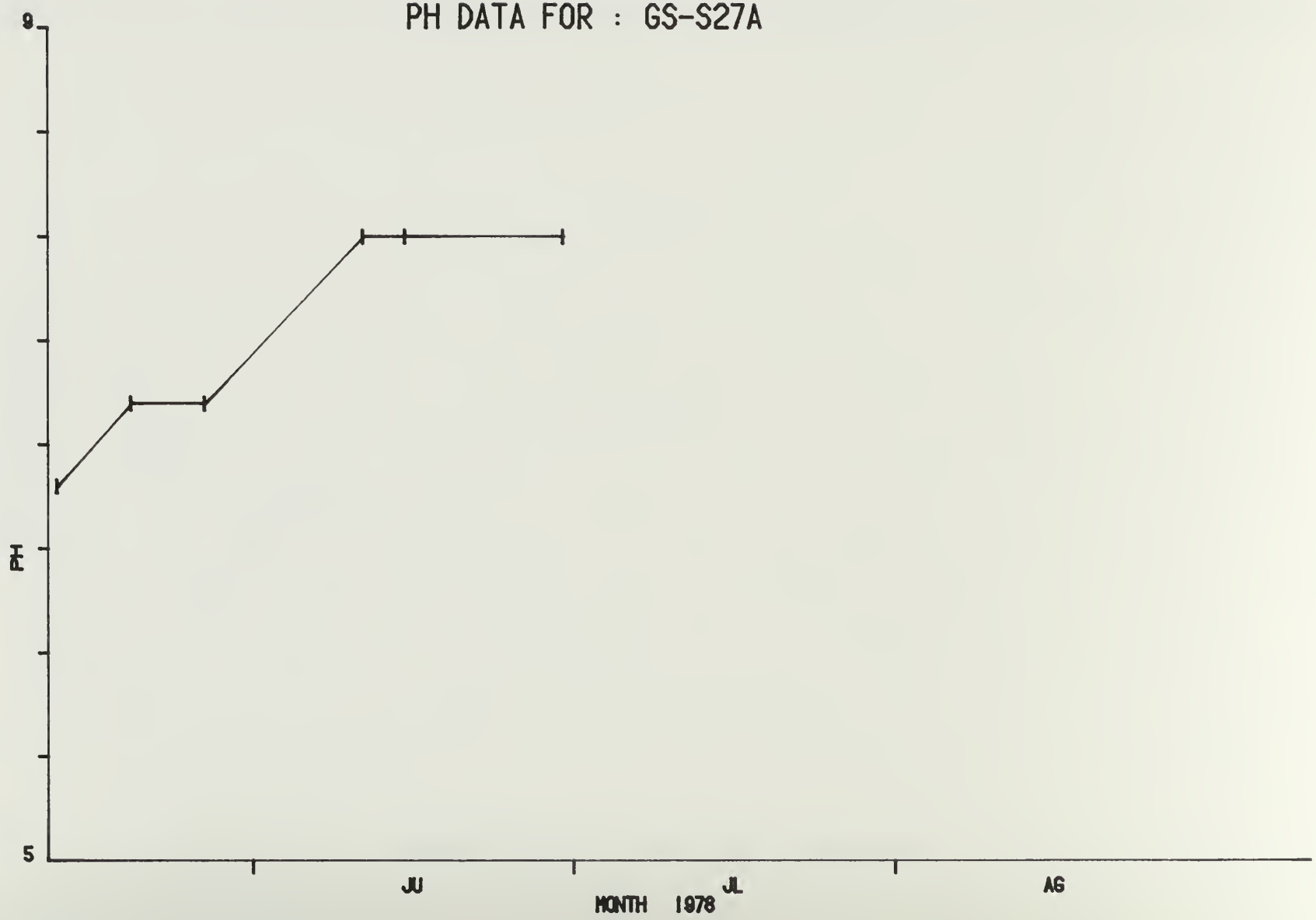


FIGURE 5-98 PH Data Hydrograph for Alluvial Hole G-S S27A, Tract C-a, 1978

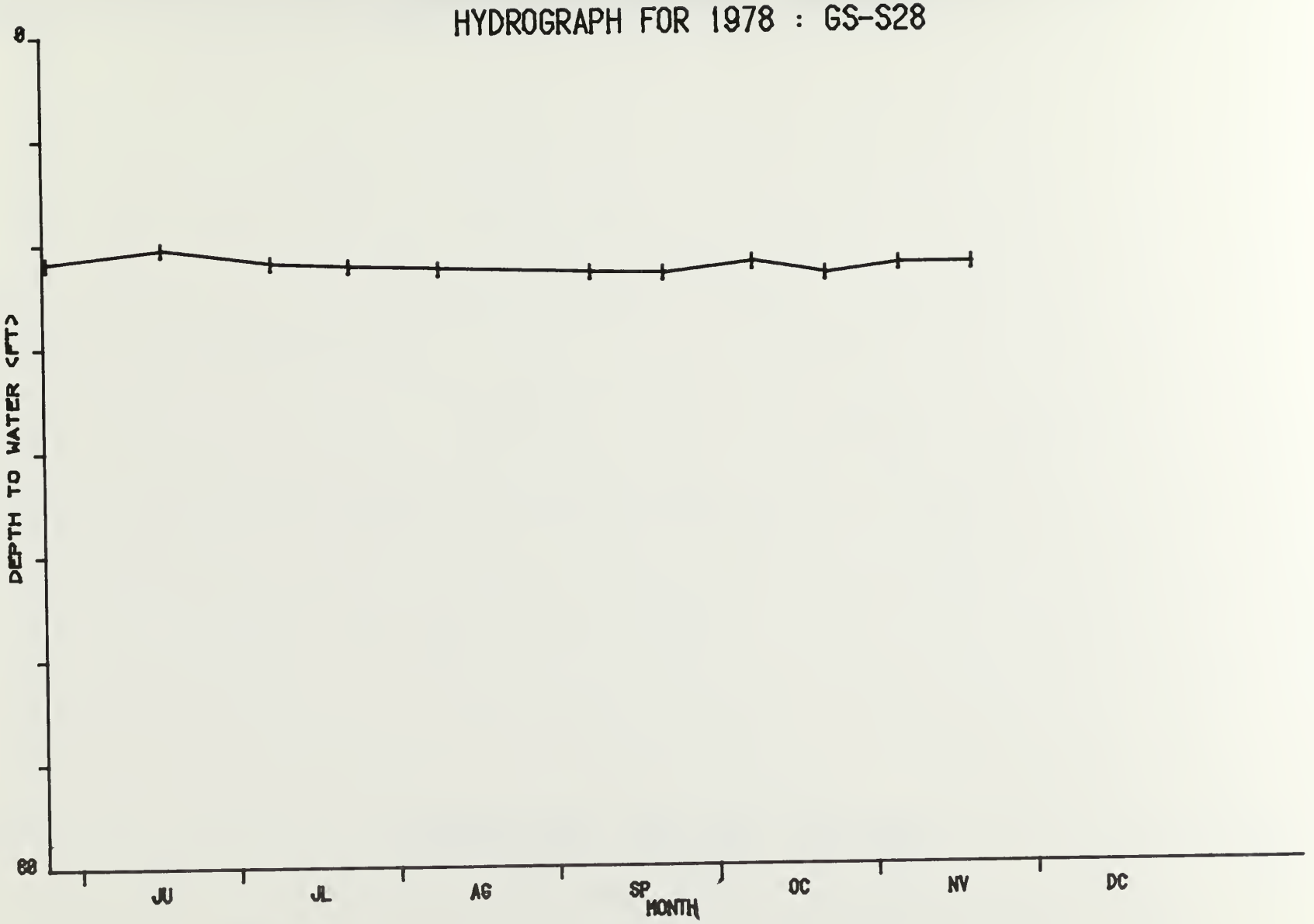


FIGURE 5-99 Water Level Hydrograph for Alluvial Hole G-S S28 Deep, Tract C-a, 1978

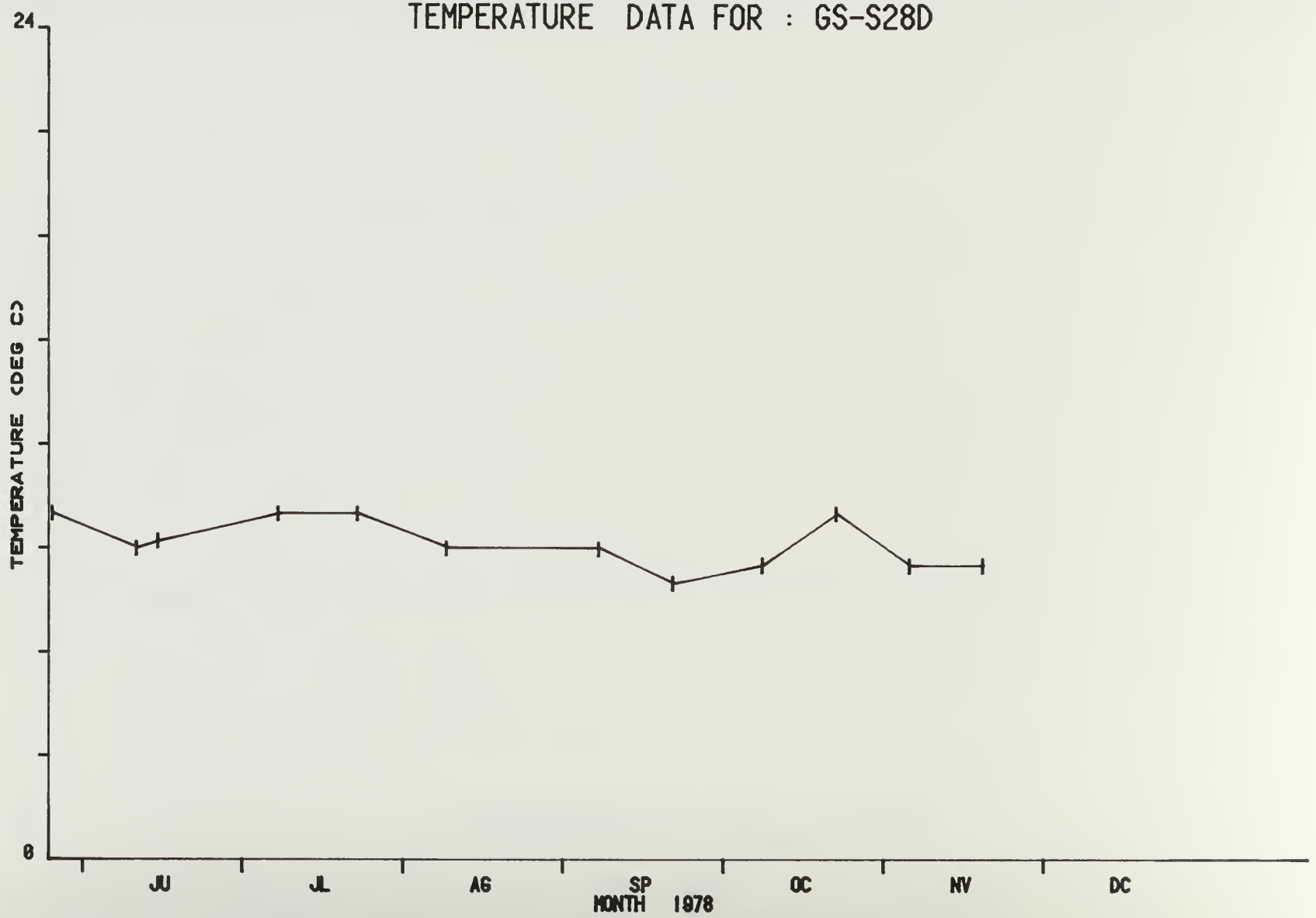
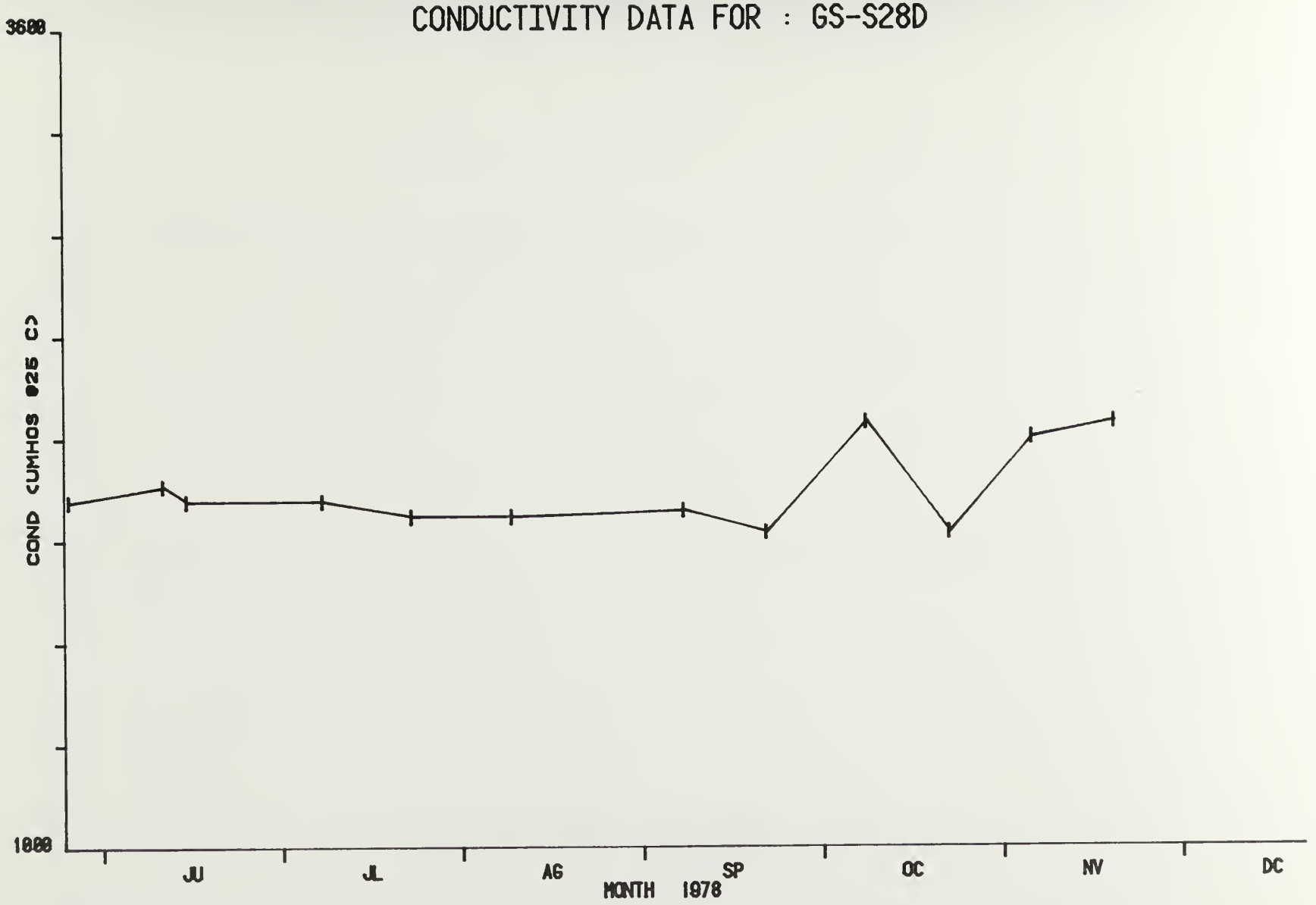


FIGURE 5-100 Temperature Data Hydrograph for Alluvial Hole G-S S28 Deep, Tract C-a, 1978



FIGUR E 5-101 Conductivity Data Hydrograph for Alluvial Hole G-S S28 Deep, Tract C-a, 1978

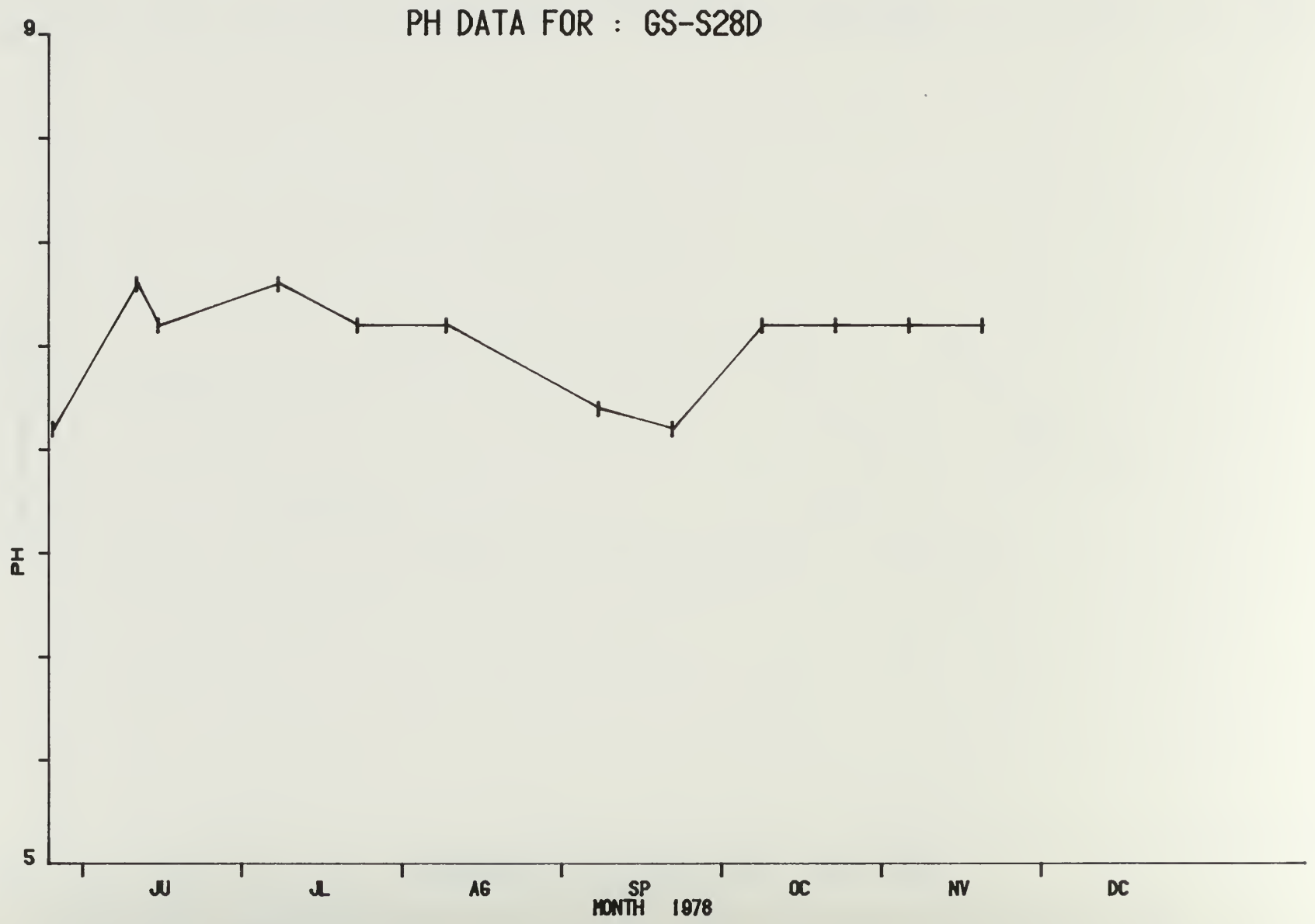


FIGURE 5-102 PH Data Hydrograph for Alluvial Hole G-S S28 Deep, Tract C-a, 1978

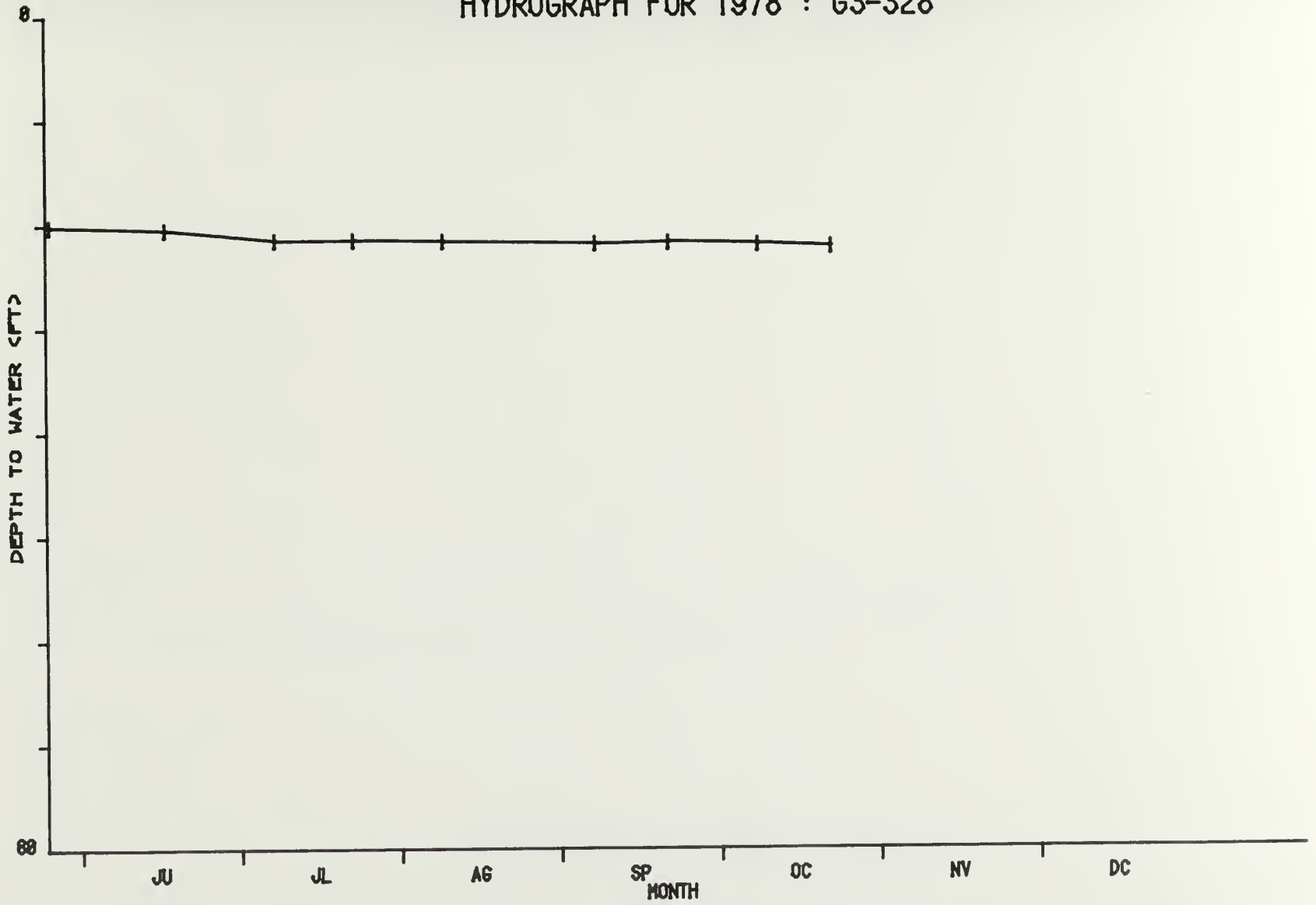


FIGURE 5-103 Water Level Hydrograph for Alluvial Hole G-S S28 Shallow, Tract C-a, 1978

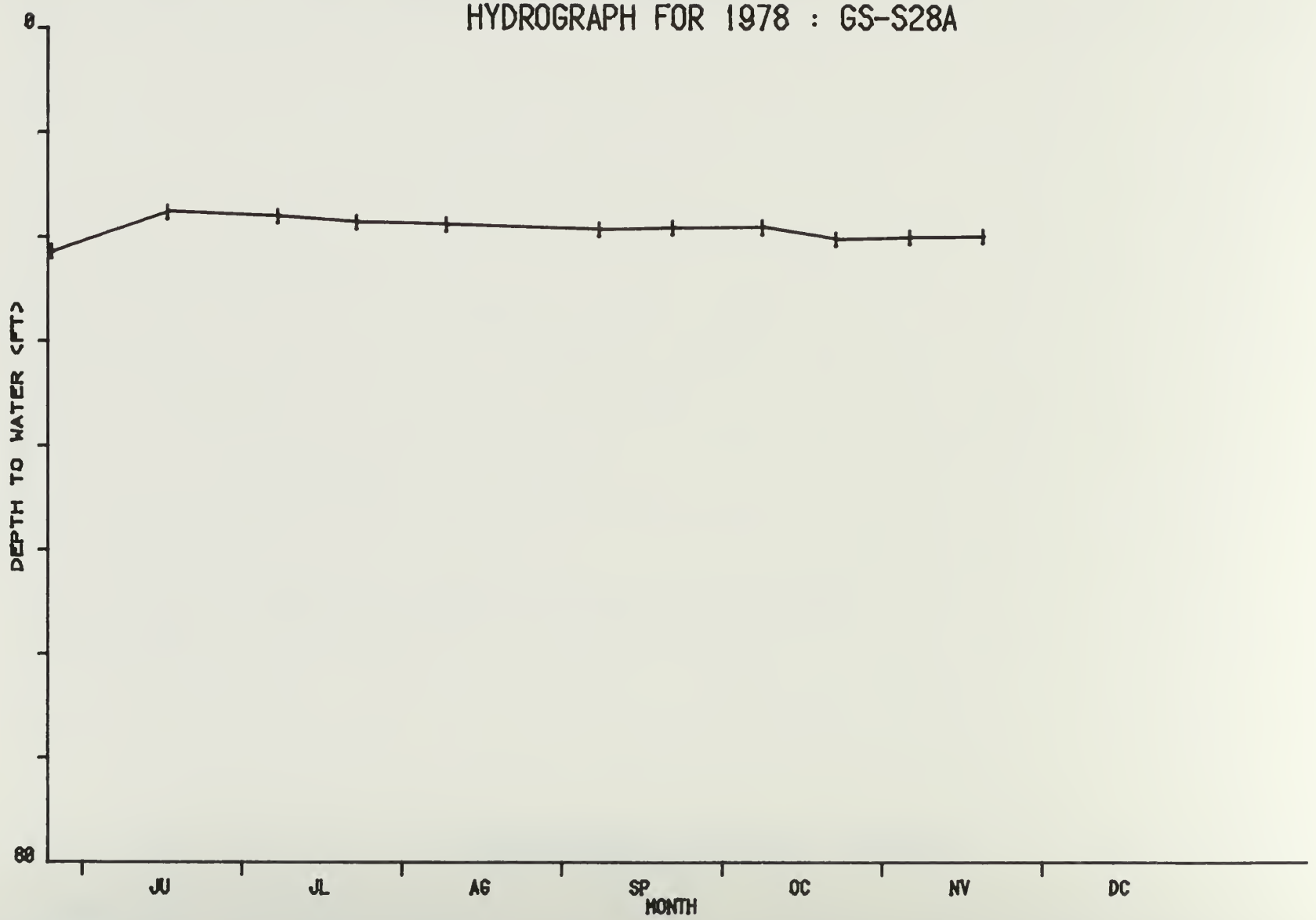


FIGURE 5-104 Water Level Hydrograph for Alluvial Well G-S S28A Deep, Tract C-a, 1978

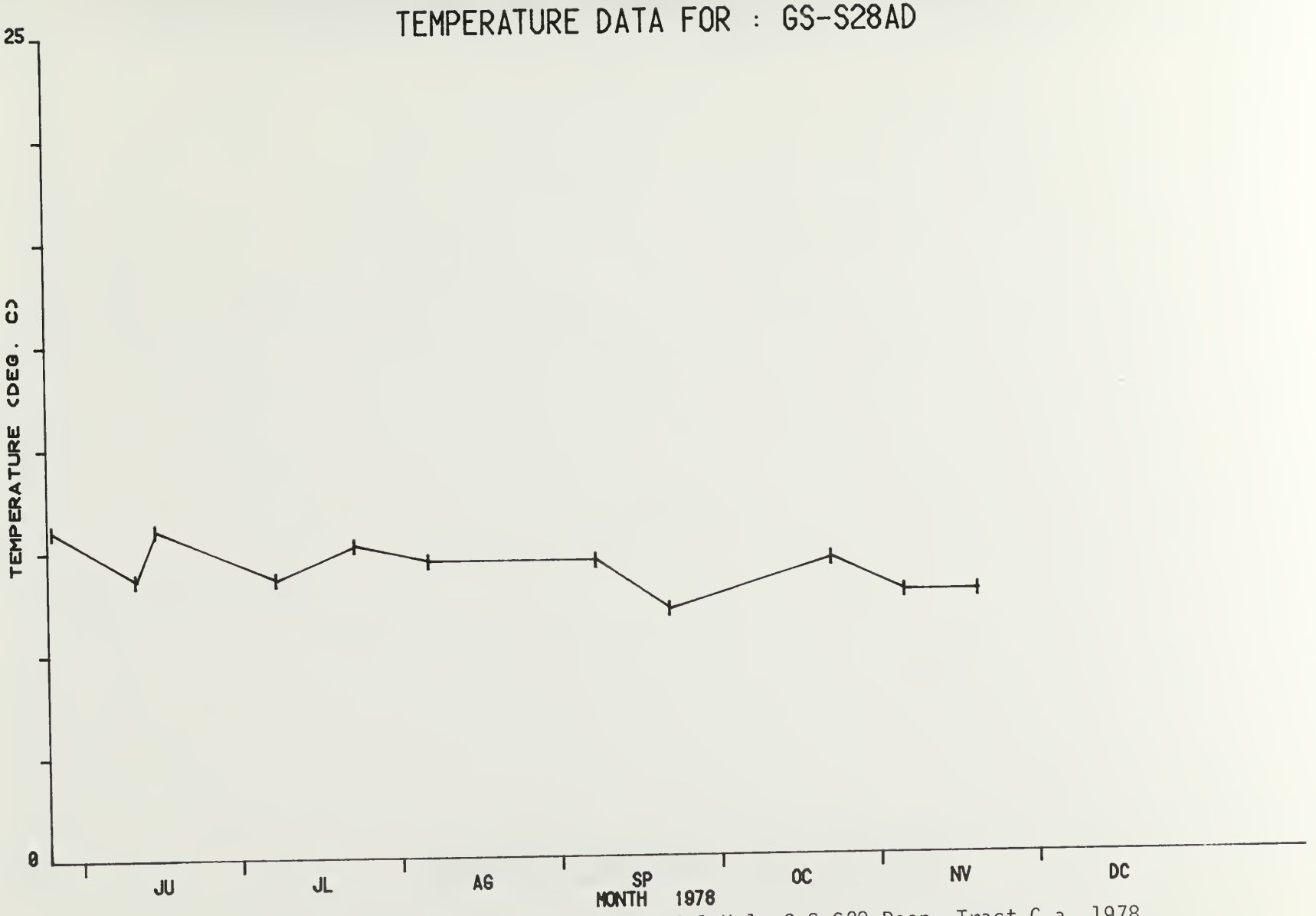


FIGURE 5-105 Temperature Data Hydrograph for Alluvial Hole G-S S28 Deep, Tract C-a, 1978

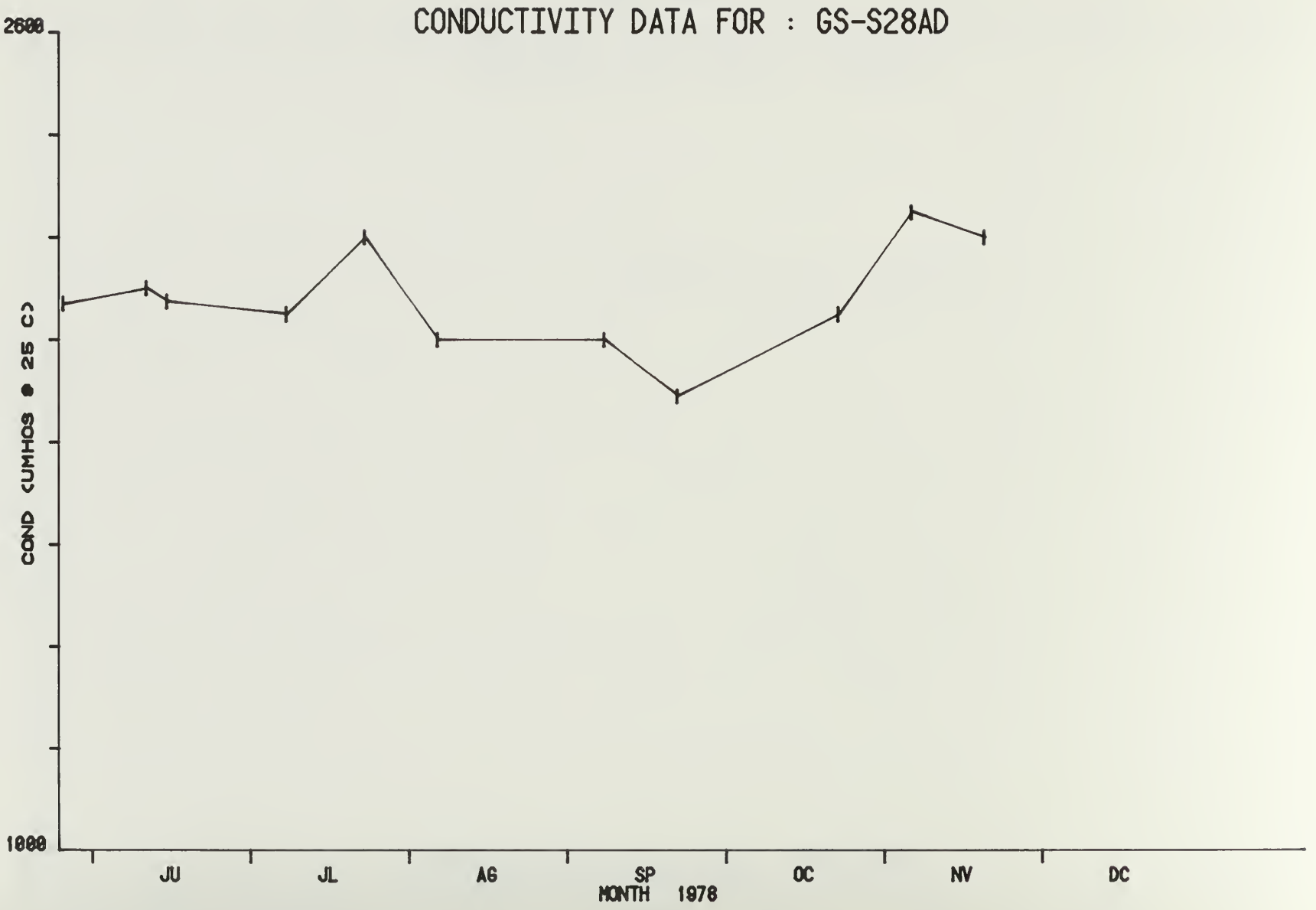


FIGURE 5-106 Conductivity Data Hydrograph for Alluvial Hole G-S S28 Deep, Tract C-a, 1978

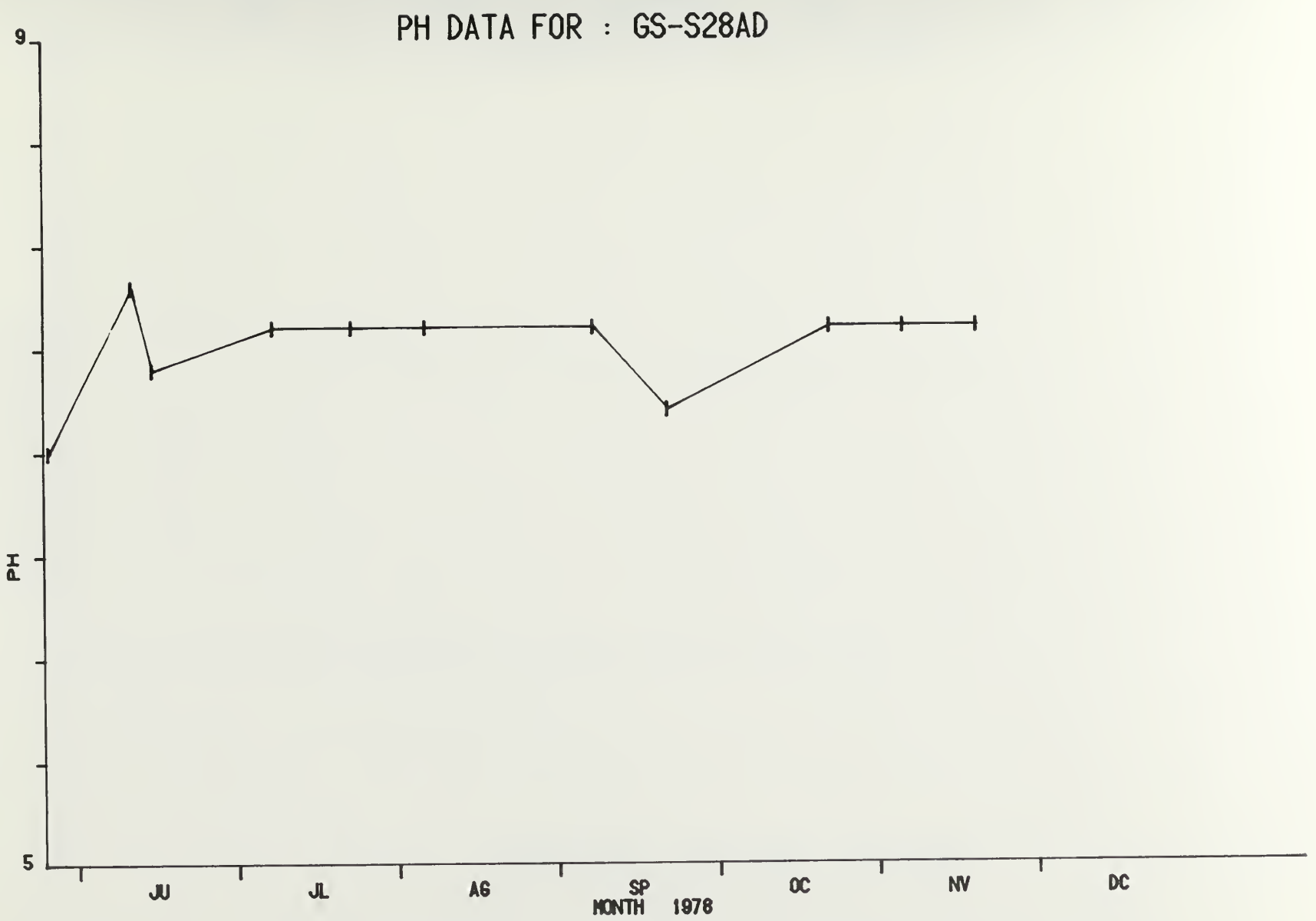


FIGURE 5-107 PH Data Hydrograph for Alluvial Hole G-S S28 Deep, Tract C-a, 1978

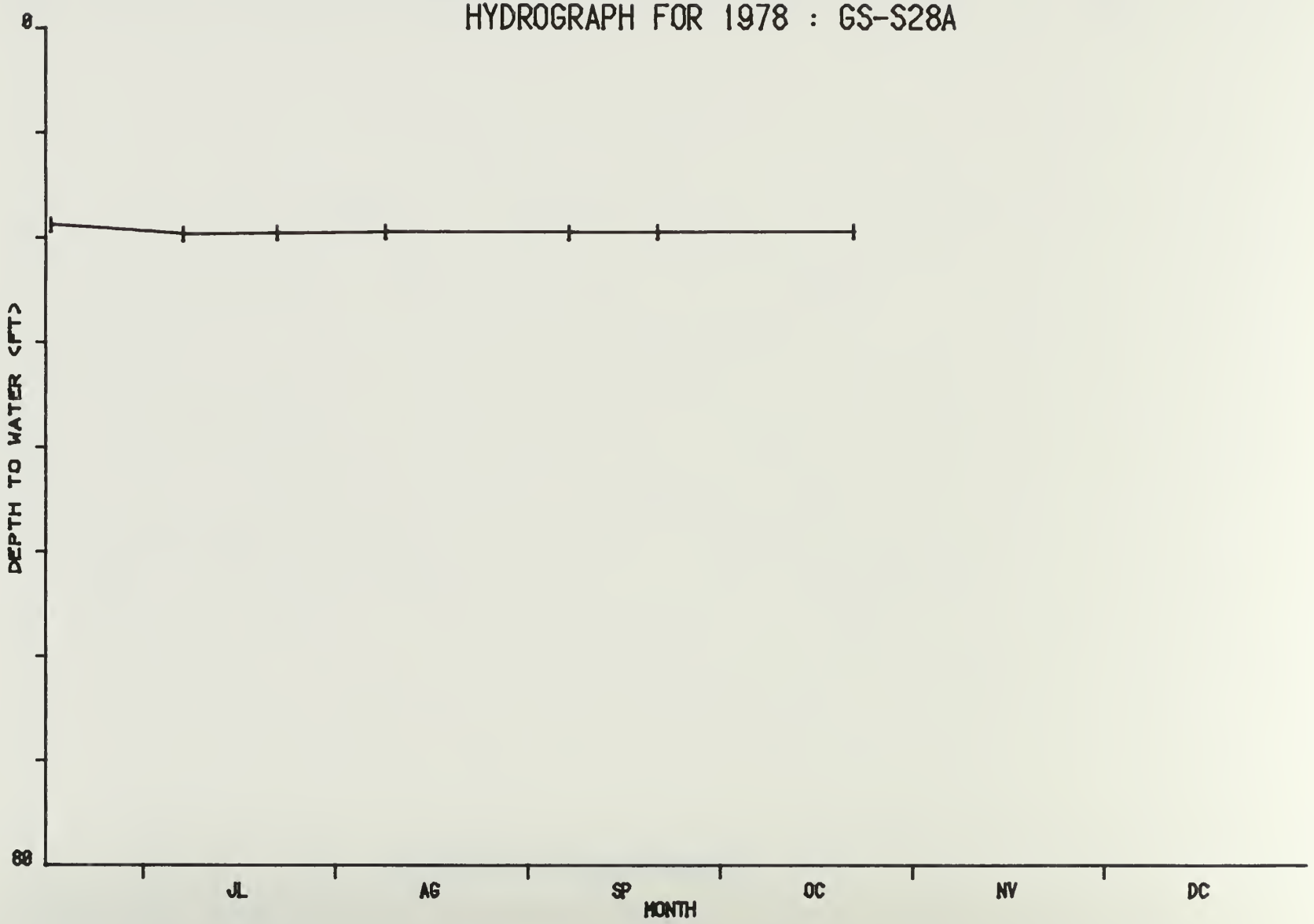


FIGURE 5-108 Water Level Hydrograph for Alluvial Hole G-S S28A Shallow, Tract C-a, 1978

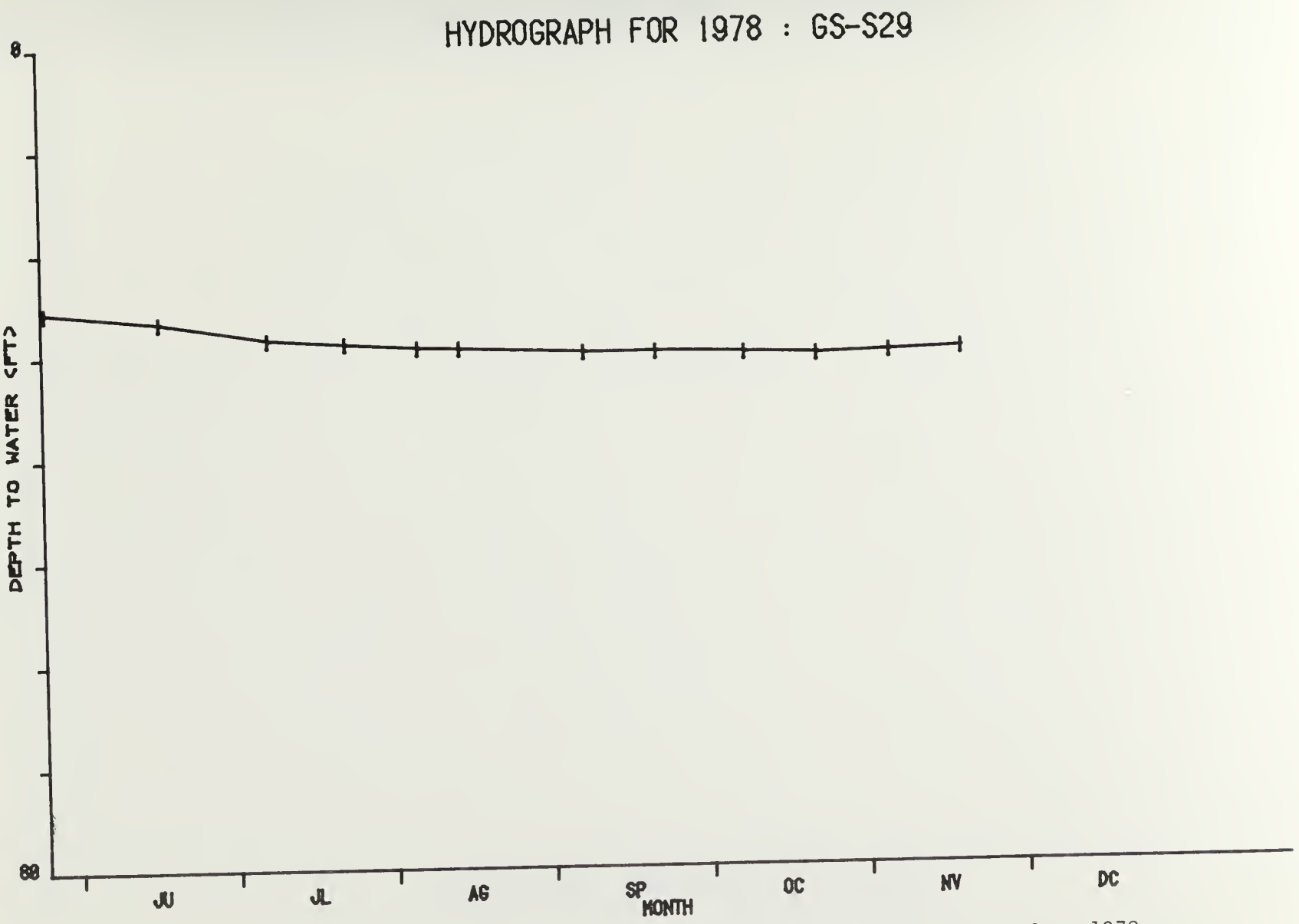


FIGURE 5-109 Water Level Hydrograph for Alluvial Hole G-S S29A Deep, Tract C-a, 1978

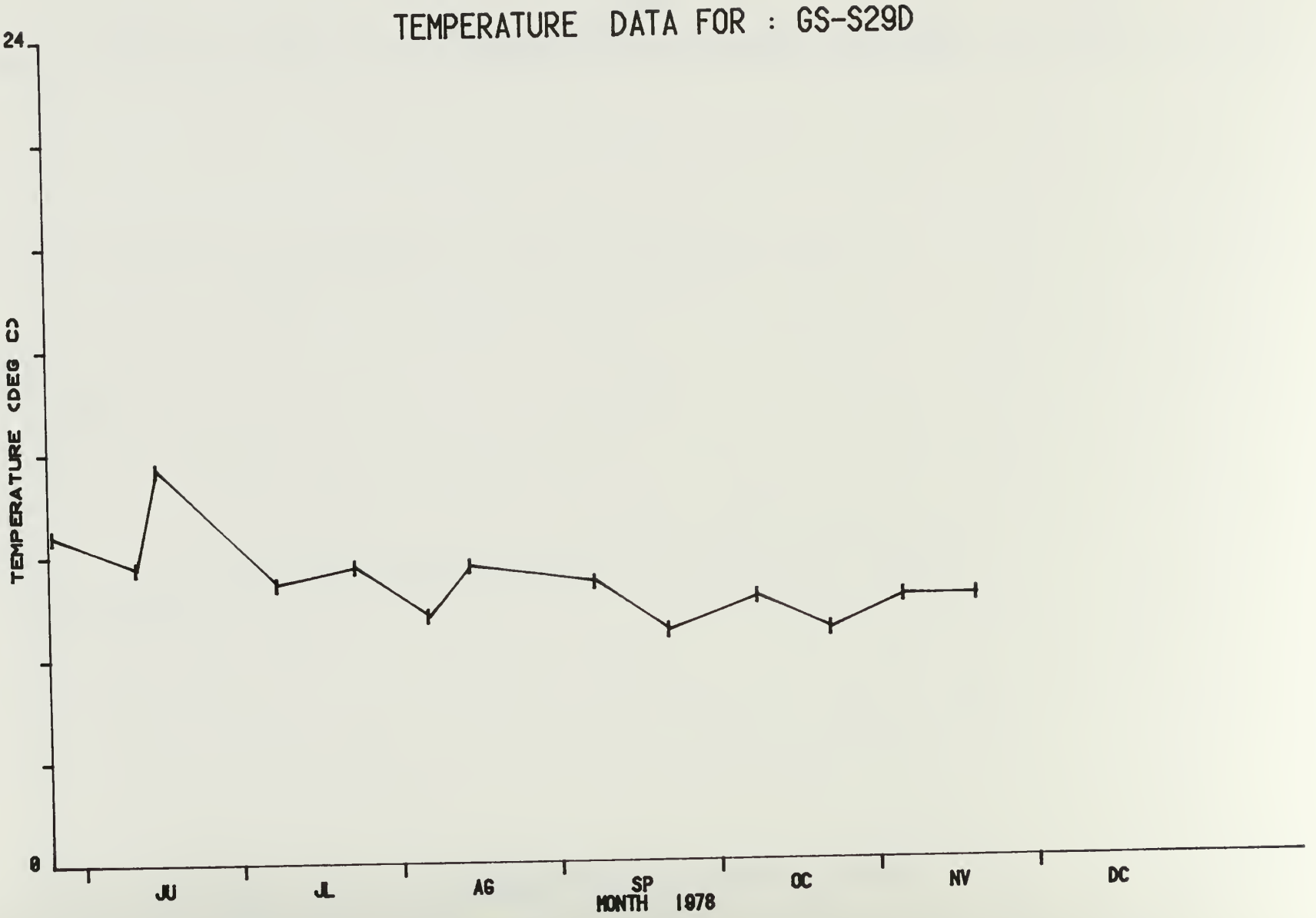


FIGURE 5-110 Temperature Data Hydrograph for Alluvial Hole G-S S29 Deep, Tract C-a, 1978

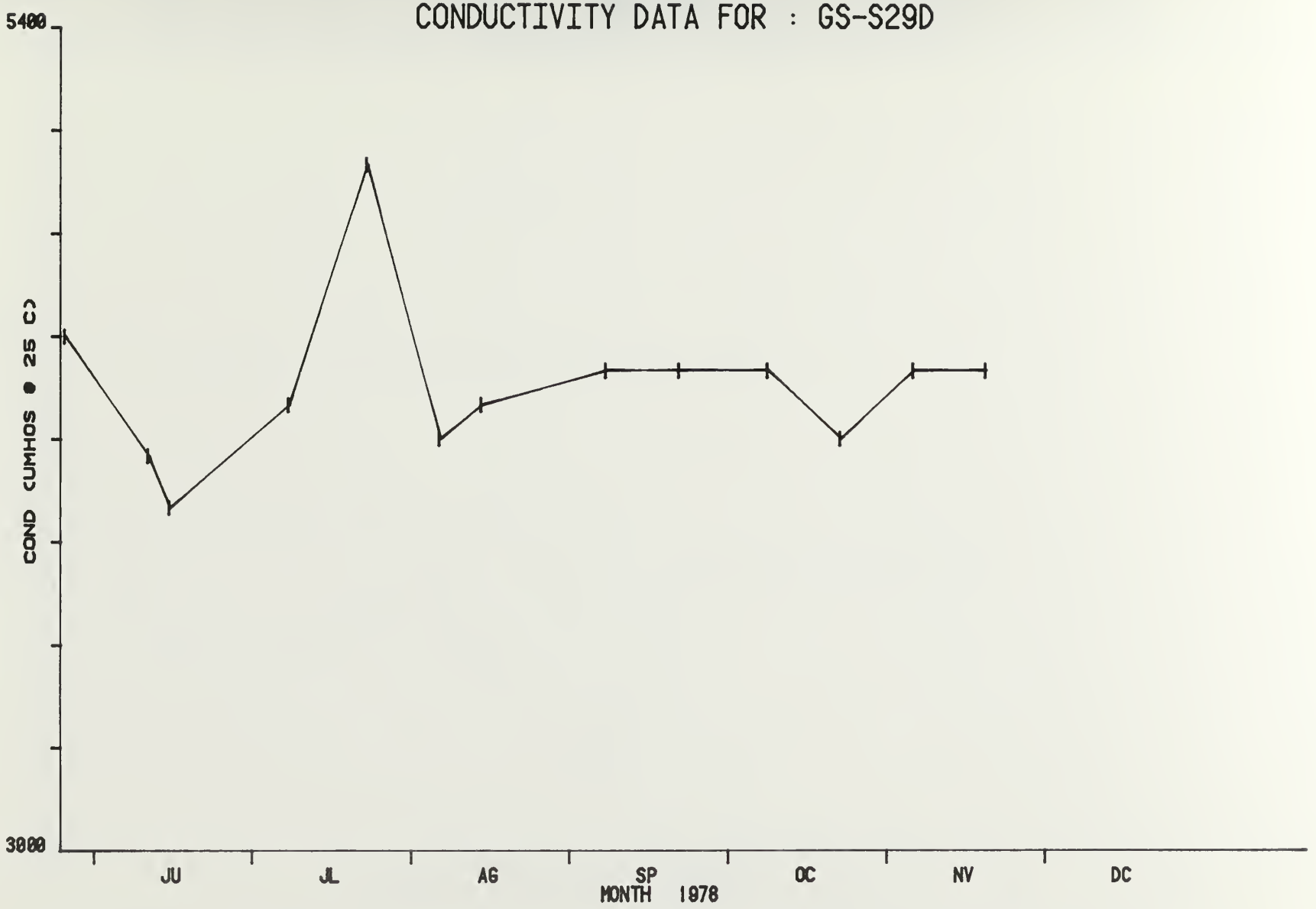


FIGURE 5-111 Conductivity Data Hydrograph for Alluvial Hole G-S S29 Deep, Tract C-a, 1978

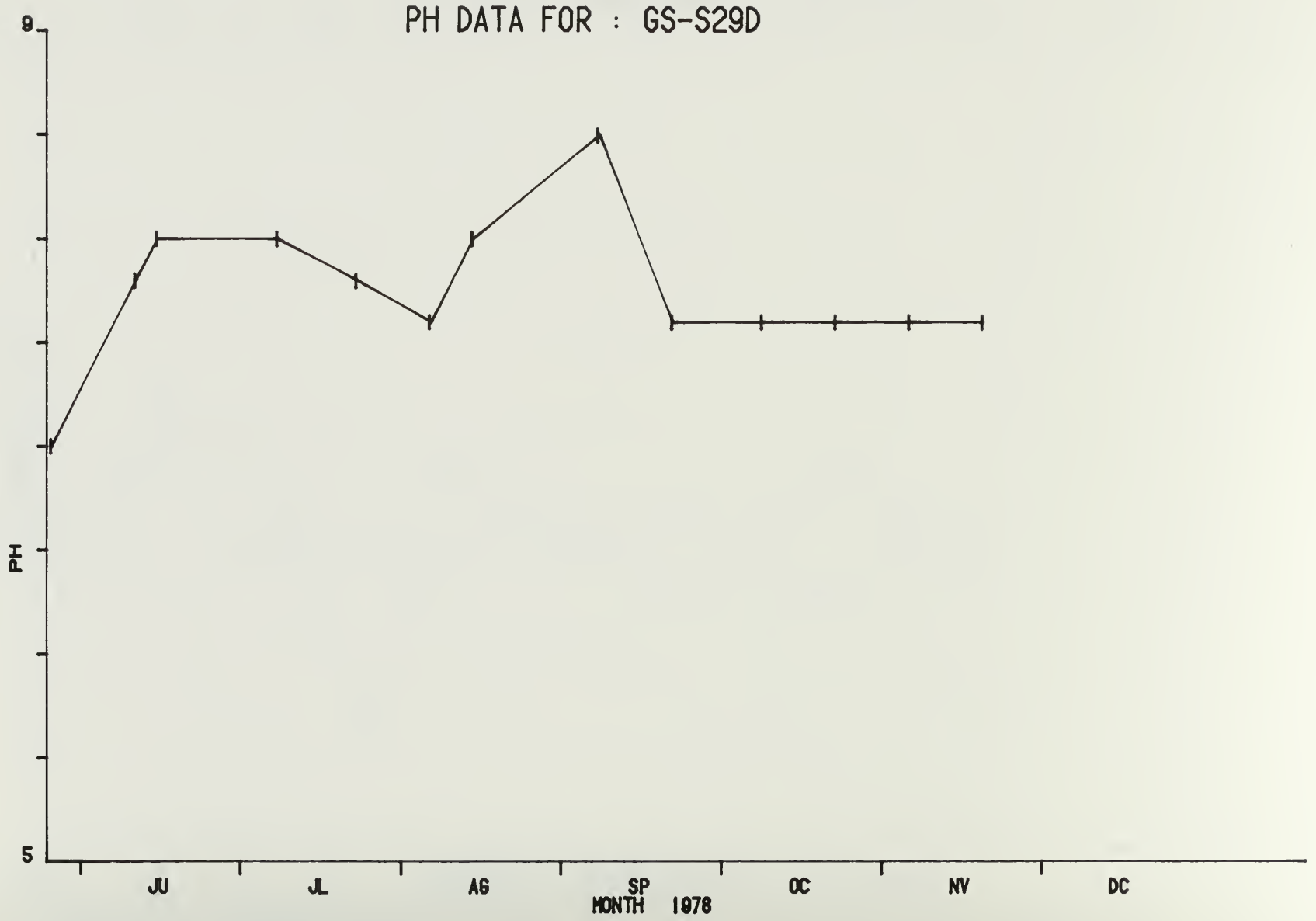


FIGURE 5-112 PH Data Hydrograph for Alluvial Hole G-S S29 Deep, Tract C-a, 1978

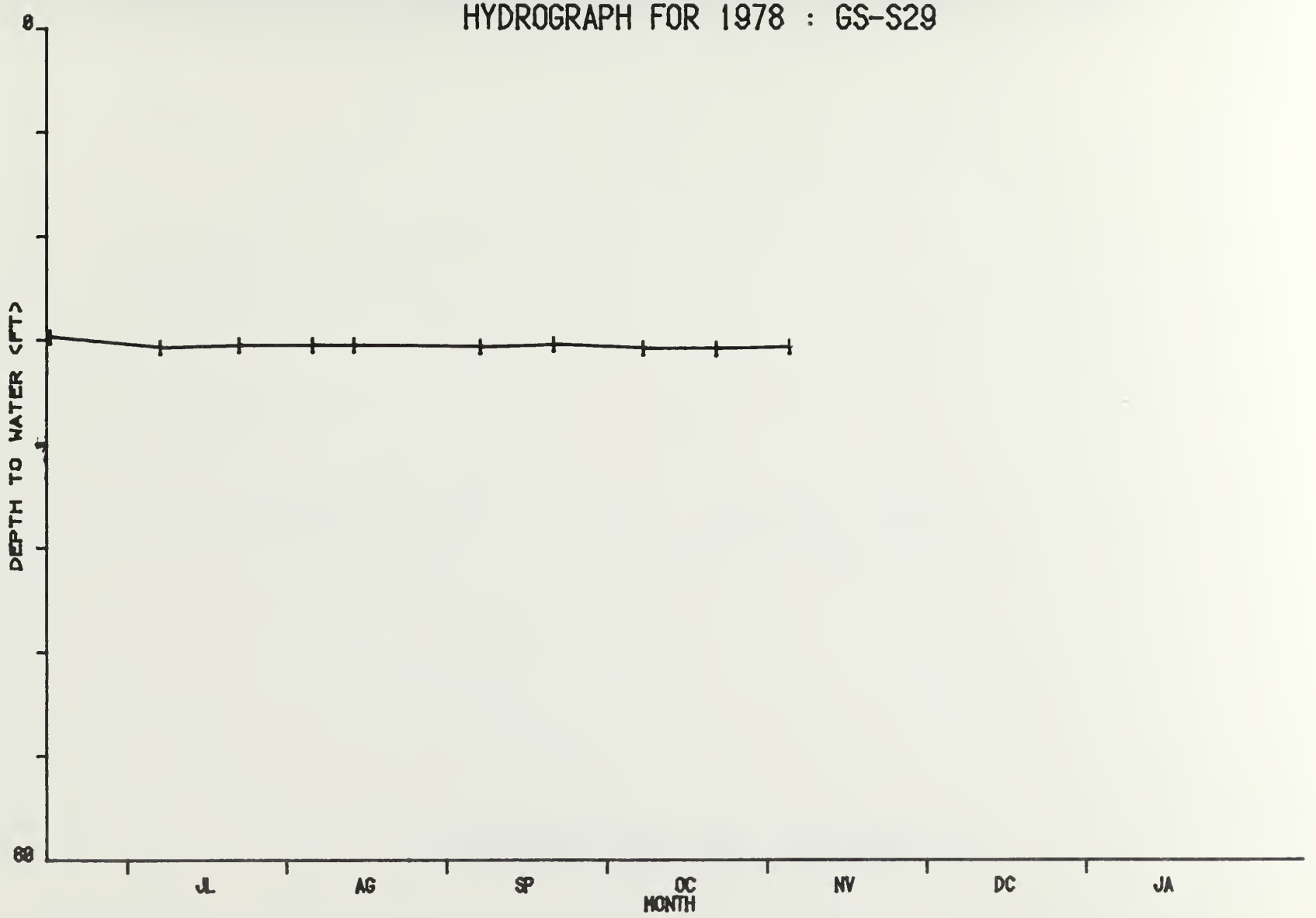


FIGURE 5-113 Water Level Hydrograph for Alluvial Hole G-S S29 Shallow, Tract C-a, 1978

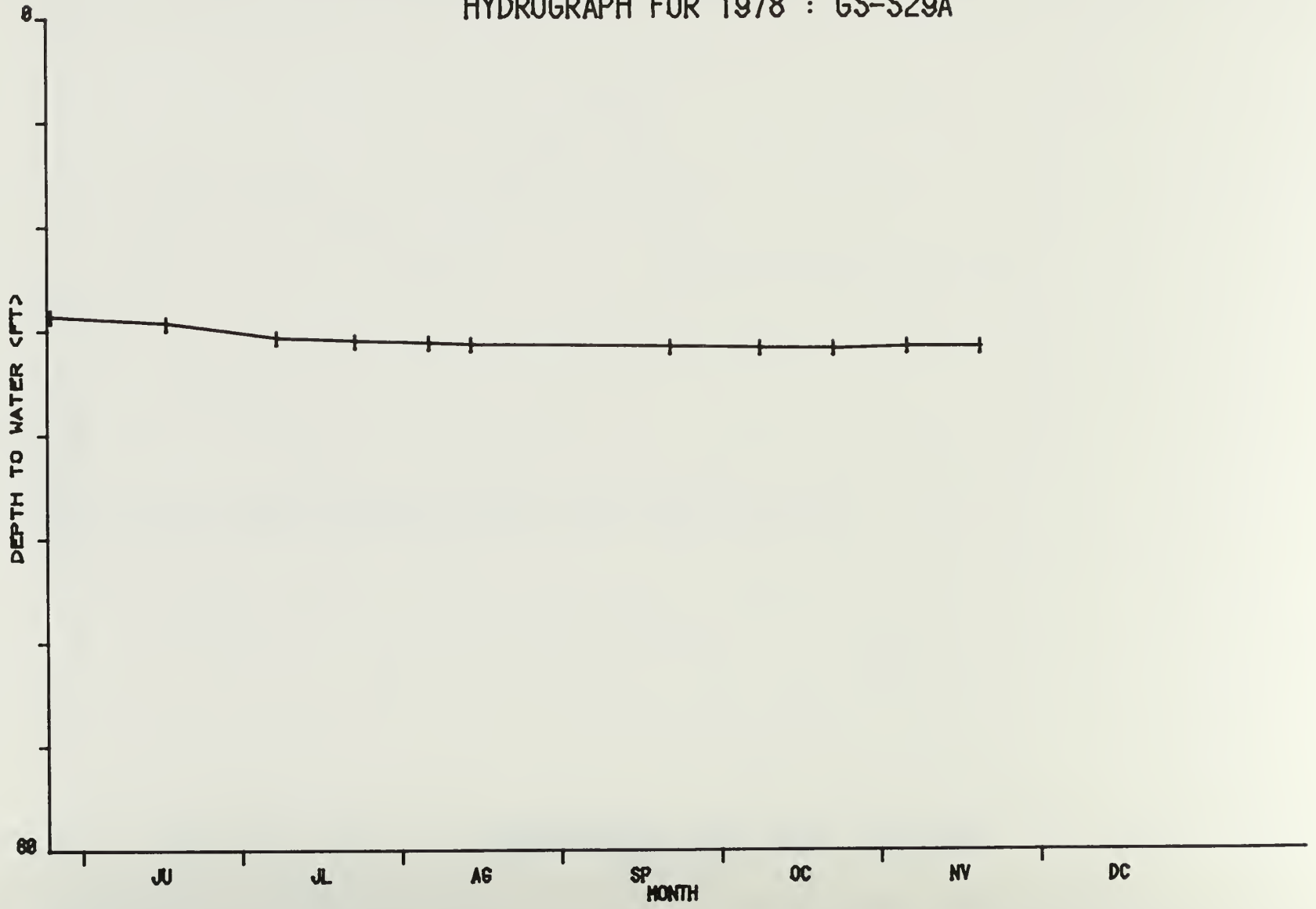


FIGURE 5-114 Water Level Hydrograph for Alluvial Hole G-S S29A Deep, Tract C-a, 1978

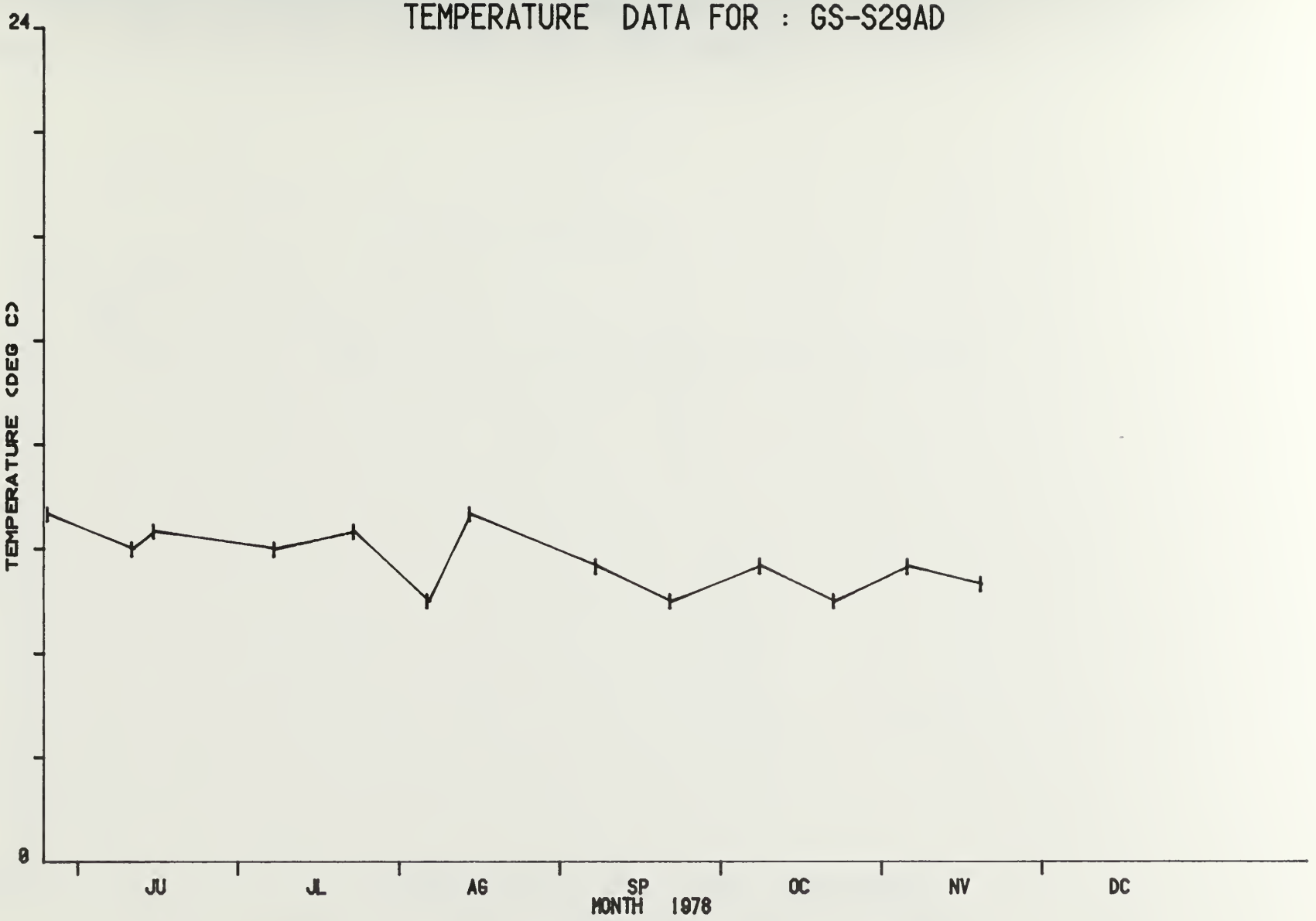


FIGURE 5-115 Temperature Data Hydrograph for Alluvial Hole G-S S29A Deep, Tract C-a, 1978

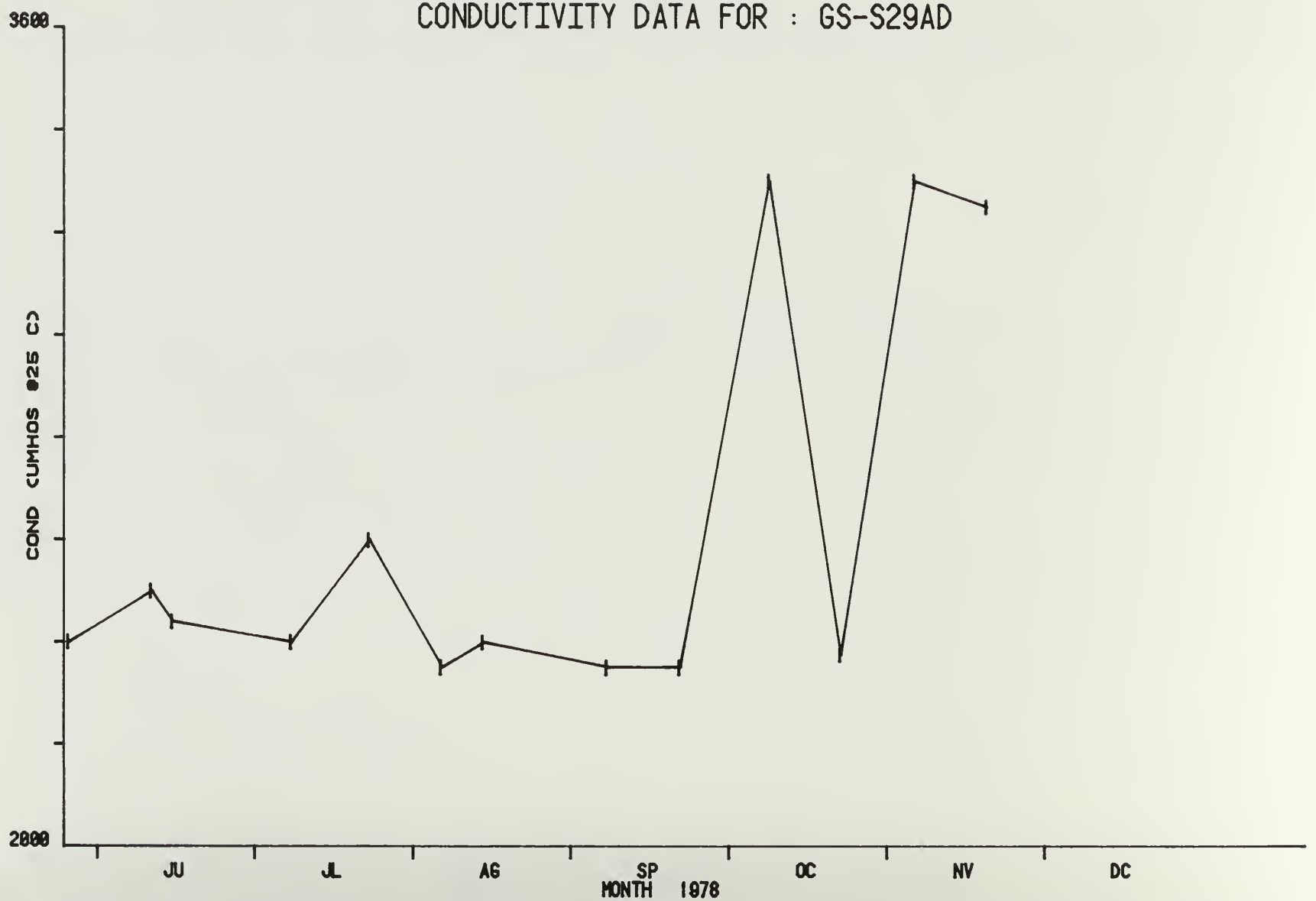


FIGURE 5-116 Conductivity Data Hydrograph for Alluvial Hole G-S S29A Deep, Tract C-a, 1973

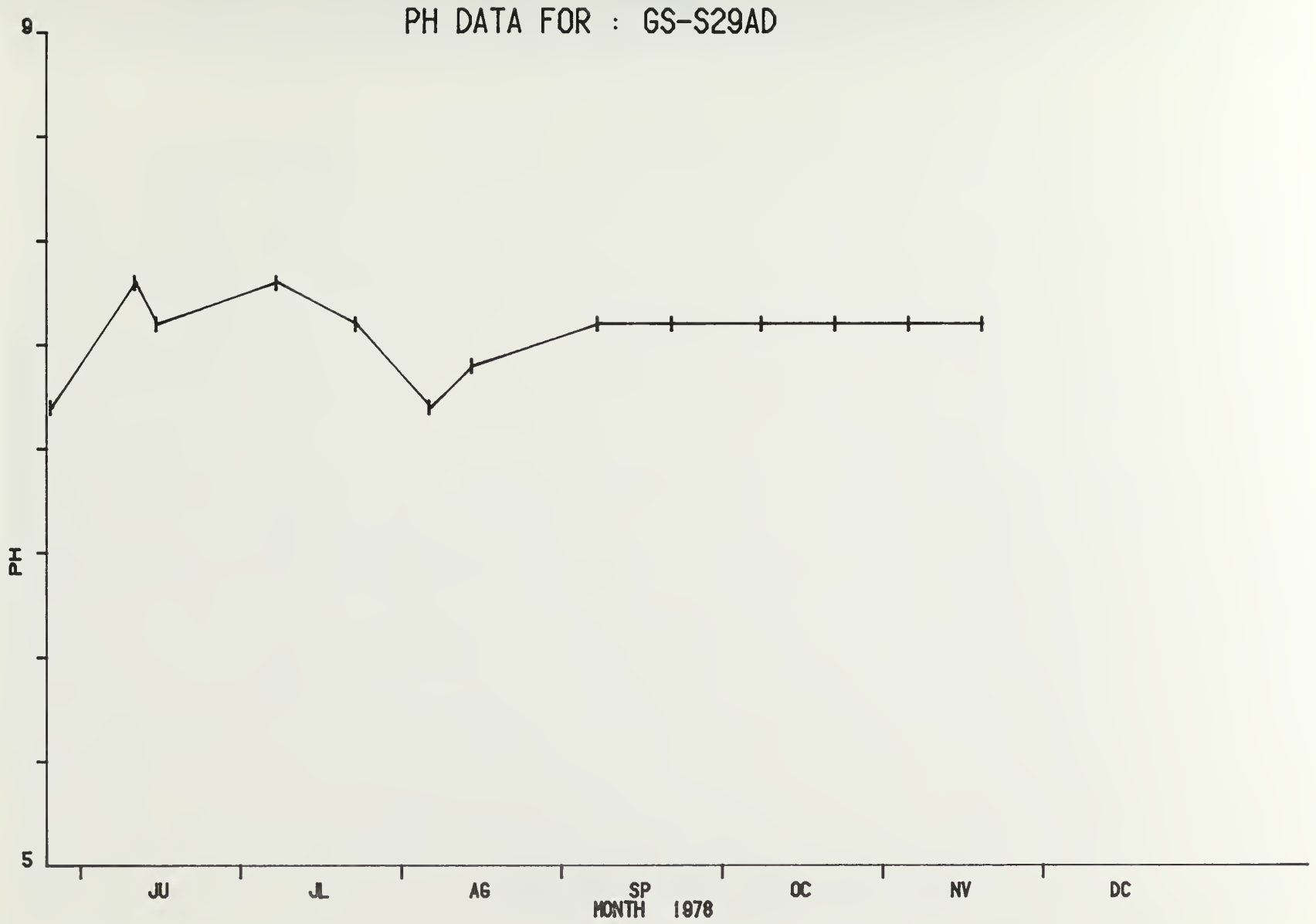


FIGURE 5-117 PH Data Hydrograph for Alluvial Hole G-S S29A Deep, Tract C-a, 1978

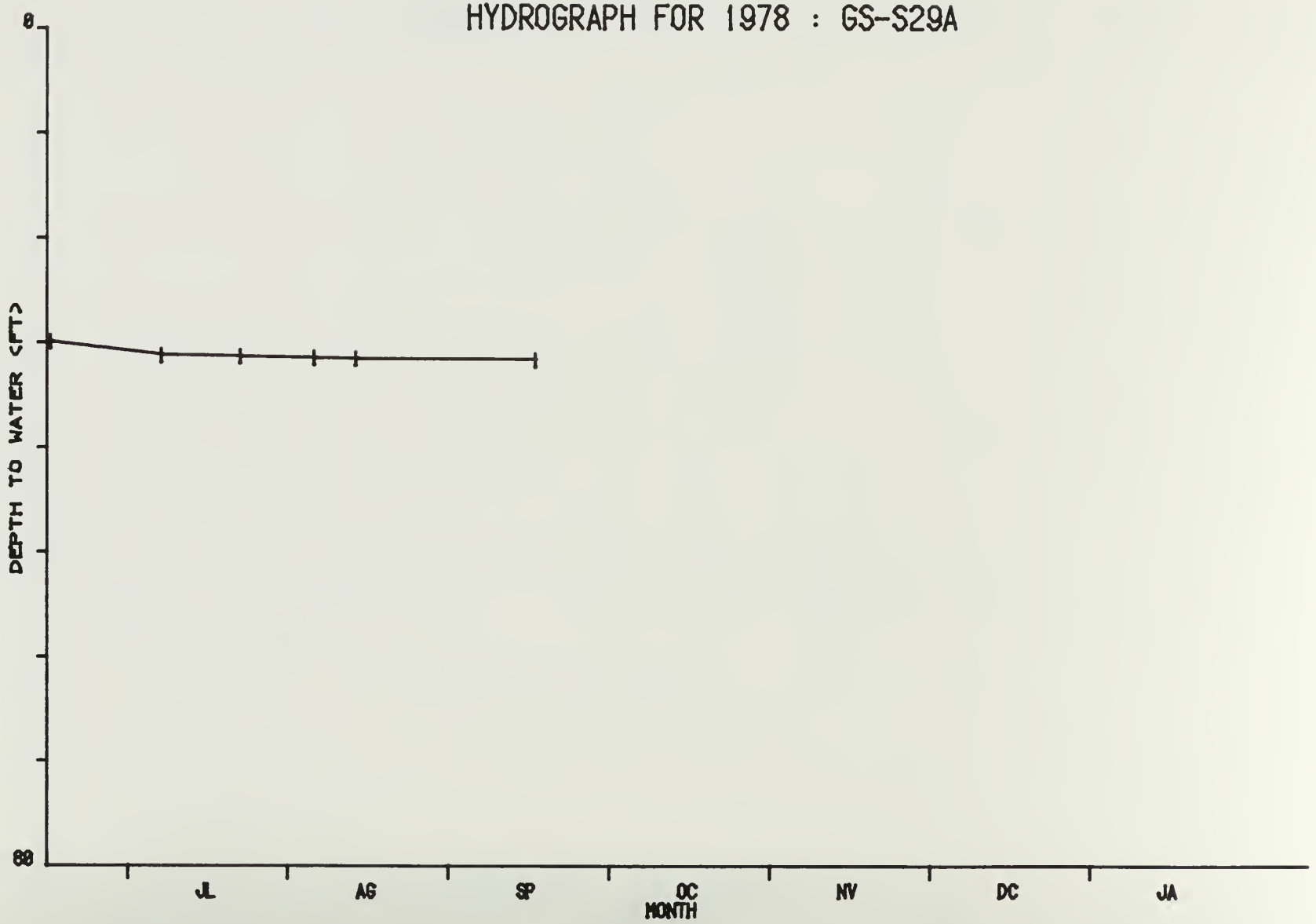


FIGURE 5-118 Water Level Hydrograph for Alluvial Hole G-S S29A Shallow, Tract C-a, 1978

The hydrograph for G-S S24 indicates a water level slightly lower than water levels measured during the baseline period. One reason for this decline in water level is the drought of 1976 and 1977. A second reason is the diversion of much of the water running down Corral Gulch to the field on the other side of Corral Gulch from this monitoring location.

TABLE 5-14 ALLUVIAL WELLS MDP PUMP TEST SUMMARY

	1978									
Well No.	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
GS-S7			X	X	C	X	X	C	C	
GS-S11s	D	D	D	D	D	D	D	D	D	D
D	C	C	C	C	C	C	C	C	C	C
GS-S11As		X	X	X	D	D	D	D	D	D
D		X	X	X	C	C	C	C	C	C
GS-S27	C	C	C	C	C	C	C	C	C	C
		L	L		B			B	B	
GS-S27A	D	D	D	D	C	X	D	D	D	D
					B					
GS-S28s					D	X	X	X	X	D
D				C	C	C	C	C	C	C
GS-S28As					X	X	X	X	X	D
D				C	C	C	C	C	C	C
GS-S29s					X	X	X	X	X	X
D				C	C	C	C	C	C	C
GS-S29As					X	X	X	X	X	D
D				C	C	C	C	C	C	C

X = Water level

C = Water level, conductivity, temperature and pH

D = Dry

B = Baseline water quality

L = Limited water quality

Data collected from G-S S27A indicates that water was present in the hole the last three weeks of May and June 1978. The hole then dried up and has not contained water since. Generally, conductivity values have generally dropped while pH has risen.

The data collected from G-S S28, G-S S28A, G-S S29, and G-S S29A indicate rather stable conditions with the exception of conductivity for G-S S29A deep. As these values cannot have been affected by tract operations, no further discussion is deemed appropriate.

The results of the water quality analysis are presented in Appendix 5-3.2 this report. The only results which differ from the baseline alluvial results are those from G-S S27A. As noted on the trilinear diagram in Section 5.2 of this report, the water from G-S S27A is entirely unlike that of any other alluvial aquifer hole. Parameters from G-S S27A which do not fall within the limits of the analysis from G-S S22 are shown on Table 5-15.

TABLE 5-15 COMPARISON OF WATER QUALITY AT G-S S27 AND G-S S27A

PARAMETER NUMBER	PARAMETER	G-S S27A VALUE	G-S S27 MAXIMUM VALUE	G-S S27 MINIMUM VALUE
0095	Conductivity (umhos)	2450	1680	
410	Alkalinity (mg/l)	185		445
440	Bicarbonate (mg/l)	160		490
445	Carbonate (mg/l)	84	42	
540	TDS (mg/l)	1620	1130	
681	DOC (mg/l)	7		8.1
915	Calcium (mg/l)	28		52
925	Magnesium (mg/l)	30		48
930	Sodium (mg/l)	500	260	
935	Potassium (mg/l)	945	520	
950	Fluoride (mg/l)	1	.6	
1080	Strontium (ug/l)	500		1200
71851	Nitrite + Nitrate (mg/l)	4.9	1.9	
71890	Mercury (ug/l)	17	2	

The two holes are approximately 100 feet apart from each other. G-S S27 is located on the south side of Corral Gulch while G-S S27A is located on the north side. The source of the water in G-S S27A can only be speculated. The hydrograph for G-S S27 indicates that the highest water levels were recorded during the months of May and June 1978. It is during these months that G-S S27A contained water.

The reason that water qualities of the two holes are so entirely different may be that G-S S27A is completed on landfill. This landfill was originally the result of the drilling of Oxy #1 some years ago. Subsequently, three holes were drilled near the visitors center which may have altered the landfill. It is our opinion that water from G-S S27A has encountered minerals which are dissolvable in the landfill and, therefore, has been contaminated by man as a result of prelease activities.

Table 5-18, Section 5.2, compares a number of constituents of G-S S24 with baseline data from the MDP data using an F-test for population equivalents. It should be noted that only depth to water and pH had greater values than those encountered during the baseline. The other three constitutents, DOC, strontium (which has already been discussed), and zinc, were found to have significantly lower values during the MDP Pump Test Monitoring than during the monitoring conducted during the baseline period.

SECTION 6
SUMMARY

In September 1977, RBOSC initiated their Modular Development Phase (MDP- Environmental Monitoring Program. The first report of MDP environmental activities (September - November 1977) was published in February 1978; the second report (December 1977 - May 1978) was published in September 1978. This is the third report describing MDP environmental activities. This report, RBOSC MDP Monitoring Report 3, presents data collected during the summer (June, July, August) and fall (September, October, November) seasons, discusses the data collected from December 1977 through November 1978, and compares MDP data with baseline and interim data.

The following is a summary of RBOSC MDP Monitoring Report 3. Some tables and figures from this report have been repeated in this summary for clarity. More detailed discussions about each discipline may be found in the appropriate section in this report.

Atmospheric Studies

The Tract C-a atmospheric studies program conducted during the reporting period consisted of two elements: (1) measurements of total suspended particulate matter and certain gaseous chemical compounds, and (2) measurements of selected meteorological parameters. The monitoring locations were originally established to measure the ambient air quality generally upwind and somewhat removed from the expected tract development, and at points where tract development might have an effect on the air quality. Simultaneous meteorological measurements were made to allow evaluations of air quality changes and for prediction of the dispersion of emissions from tract development.

The level of activity on the tract, principally construction work, has increased significantly during the MDP period. The monitoring program has also been increased in order to measure possible effects on the ambient air quality. Two of the sites that had been previously deactivated were refitted with meteorological instrumentation and put back on-line during the first quarter of the MDP. In addition, one of the reactivated meteorological sites is gradually being refitted with a set of air quality instrumentation. This is scheduled to be completed

by September 1979. The ambient air studies monitoring network is depicted on Figure 6-1. Parameters measured during the reporting period, the locations at which they were taken, the date of start-up, and the frequencies of measurement are described on Table 6-1.

As part of the year-end report, an intensive analysis has been carried out on the data obtained during the most recent four quarters of the MDP program (December 1977 - November 1978, hereafter referred to as the current year). Comparisons have been made with the results from the baseline period (February 1975 - January 1977), obtained from the Final Environmental Baseline Report. A summary of these analyses follows:

- Sulfur Dioxide - Hourly average concentrations recorded were between 0.01 and 0.03 ppm at Site 1 and between 0.01 and 0.11 ppm at Site 3, with most of the values at both sites less than the reliable threshold of detection (0.02 ppm). Annual mean concentrations at both sites for the current MDP period were below the reliable threshold of detection and were therefore set at 0.01 ppm. Mean concentrations during the baseline period were also below the reliable threshold of detection.

- Hydrogen Sulfide - Hydrogen sulfide hourly average concentrations recorded at Site 1 were between 0.01 and 0.04 ppm and at Site 3 were between 0.01 and 0.55 ppm. The annual means at both Site 1 and Site 3 for the current year were 0.01 ppm which are below the reliable threshold for hydrogen sulfide. The annual means at both sites during each of the baseline years were also below the reliable threshold of detection. A few elevated concentrations appeared at Site 3. These were apparently caused by the surface discharge of underground water which contains reduced sulfur compounds. Site 3 is located near the creek into which the groundwater was discharged.

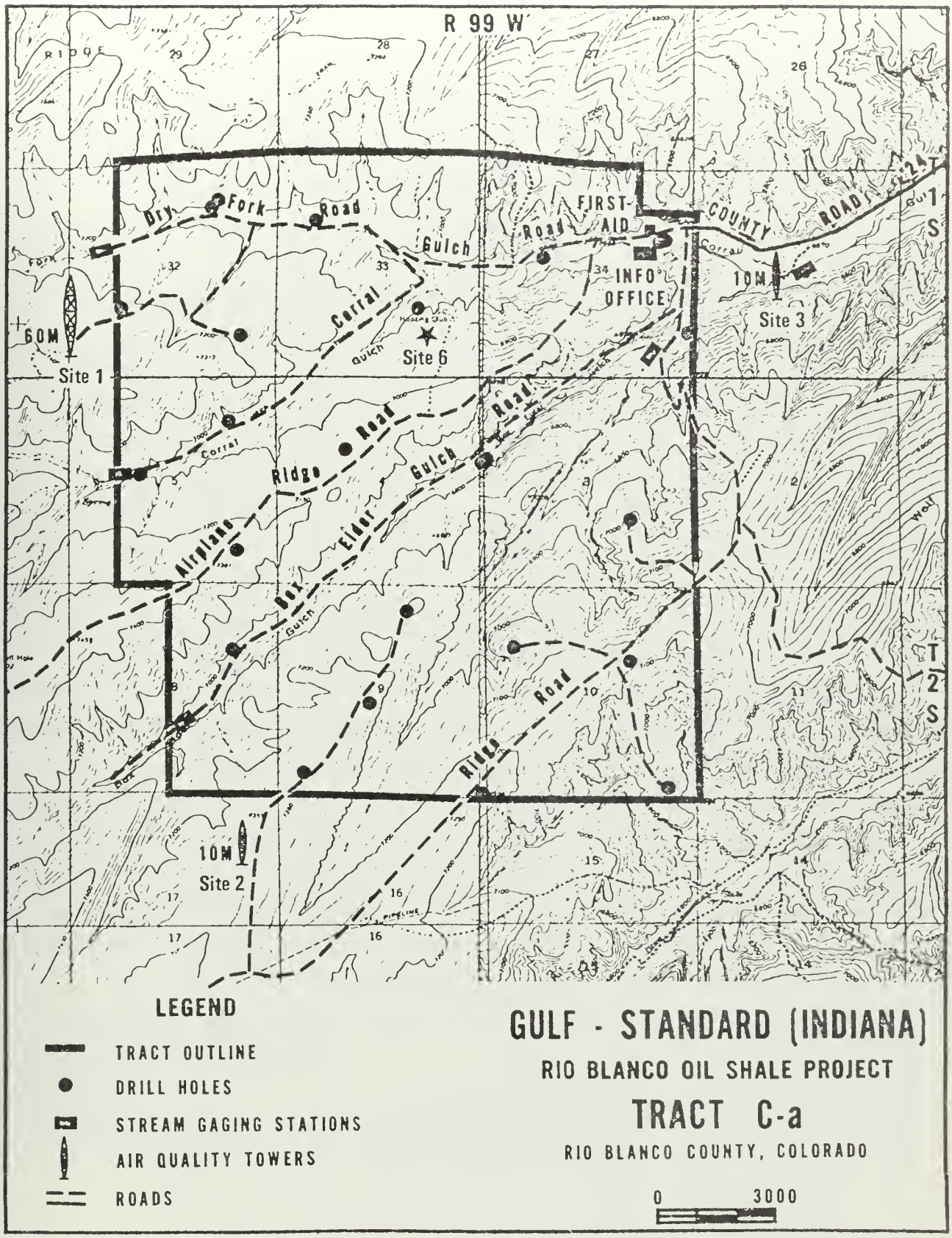

R 99 W
Dry Fork Road
Gulch
Road
FIRST-AID
INFO OFFICE
COUNTY ROAD
Corral
60M
Site 1
Site 6
10M
Site 3
Ridge Road
Gulch
Allegiance
Box Elder Gulch
Road
10M
Site 2
T 2 S
LEGEND
TRACT OUTLINE
DRILL HOLES
STREAM GAGING STATIONS
AIR QUALITY TOWERS
ROADS
GULF - STANDARD (INDIANA)
RIO BLANCO OIL SHALE PROJECT
TRACT C-a
RIO BLANCO COUNTY, COLORADO
0
3000

Figure 6-1

TABLE 6-1. AIR STUDIES MONITORING PARAMETERS AND PROGRAM SCHEDULE

Parameter	Location	Start Date	Frequency
Sulfur Dioxide	Sites 1, 3	Nov. 1977	Continuously
	Sites 2, 5	June 1979	Continuously
Oxides of Nitrogen	Site 1	Oct. 1977	Continuously
	Site 3	June 1979	Continuously
Nitric Oxide	Site 1	Oct. 1977	Continuously
	Site 3	June 1979	Continuously
Hydrogen Sulfide	Site 1, 3	Nov. 1977	Continuously
Carbon Monoxide	Site 1	Oct. 1977	Continuously
	Site 3	June 1979	Continuously
Hydrocarbons**	Site 1	Oct. 1977	Continuously
Ozone	Sites 1, 3	Oct. 1977	Continuously
Nitrogen Dioxide*	Site 1	Oct. 1977	Continuously
	Site 3	June 1979	Continuously
Particulates	Site 1, 2, 3	Oct. 1977	Every 4th day
	Site 6**	Nov. 1977	Every 4th day
Wind direction (10m)	Sites 1, 2, 3	Oct. 1977	Continuously
Wind direction (60m)	Site 1	Oct. 1977	Continuously
Wind speed (10m)	Sites 1, 2, 3	Oct. 1977	Continuously
Wind speed (60m)	Site 1	Oct. 1977	Continuously
Wind sigma (10m)	Site 1	Oct. 1977	Continuously
Ambient temperature (10m)	Sites 1, 2, 3	Oct. 1977	Continuously
Temperature (10-60m)	Site 1	Oct. 1977	Continuously
Precipitation	Site 1, 2, 3 & other selected locations	Oct. 1977	Periodically
Solar radiation	Site 1	Oct. 1977	Continuously
Dewpoint (10m)	Site 1	Feb. 1978	Continuously
Visibility	Visibility Shelter		Semi-annually
Noise	15 locations on tract		Quarterly

* by mathematical calculation.
**discontinued by permission.

- Nitrogen Oxides - The highest hourly average concentrations for nitrogen oxides and nitric oxide were 0.023 and 0.016 ppm, respectively. The arithmetic means for the period for nitrogen oxides and nitric oxide during both baseline years and the current year are below the reliable threshold of detection of 0.01 ppm.

- Carbon Monoxide - No measurements of carbon monoxide were reported above the reliable threshold of the instrument. The mean carbon monoxide concentrations during the baseline period at both sites were also below the reliable threshold of detection of 1.0 ppm.

- Hydrocarbons - Measurements were made only from December 1977 through February 7, 1978. Thereafter they were discontinued in consultation with the AOSO.

- Ozone - The range of ozone concentrations for the current year was 0.017 to 0.088 ppm at Site 1 and 0.004 to 0.072 ppm at Site 3. The Site 1 mean ozone concentration of 0.057 ppm during this data period contrasts with mean concentrations of 0.033 and 0.035 ppm found at Site 1 during the two baseline years. Better agreement was found with the Site 3 mean ozone concentrations: 0.038 ppm during the current year, and 0.030 and 0.032 ppm during the two baseline years. Variations in calibration procedures probably affected these values. An extensive analysis of the ozone data has been carried out in an attempt to develop a better understanding of the sources of ozone measured on the tract, particularly during periods of elevated concentrations. This is discussed in Section 2 of this report.

- Particulates - Quarterly and annual geometric mean and maximum values of the particulate data for the current year at each of the four sites are presented in Monitoring Report 3. The highest values were recorded at Site 6, which is immediately adjacent to the main MDP construction site.

Twenty-seven percent of the data for Site 6 exceeded the federal 24-hour average primary standard for particulates of 260 ug/m^3, and 41 percent exceeded at least the secondary standard of 150 ug/m^3. However, Site 6 is considered anomalous in that it is located immediately adjacent to the MDP construction site where fugitive dust affects the data. The only other violation recorded was one violation of the secondary standard at Site 3.

Detailed analyses performed on the particulate data are described in the year-end report. The following conclusions were drawn from these analyses:

- There is a significant difference in the particulate concentrations during periods with and without snow cover.

- Particulate concentrations measured at Sites 1 and 2 are very highly correlated.

- The meteorological parameters were most effective in predicting particulate concentrations at Site 3 while site activity predictors were surprisingly unimportant.

- At least one-third of the total variability in particulate concentrations at each site is still unexplained.

- Temperature and Stability - The monthly mean temperatures for the three sites were very similar with Site 3 generally slightly lower during the fall and winter months. The mean annual temperatures were 7.6°C at Site 1, 7.9°C at Site 2, and 6.7°C at Site 3. Absolute maximum temperatures and absolute minimum temperatures at Site 1 and Site 2 were very similar. At site 3, more extreme absolute maximum and minimum temperatures than at Site 1 and Site 2 were the rule for every month. The highest on site temperature of 32.4°C

occurred in July at Site 3, and tne lowest on site temperature of -23.1°C occurred in January at Site 3. Similarly, the average daily maximum and minimum temperatures at Site 3 were more extreme than those at Site 1 and Site 2.

- Dewpoint and Relative Humidity - The mean annual relative humidity during the two baseline years was 36 and 31 percent, as compared to 34 percent during the current year.

- Wind Speed and Wind Direction - During the current year, the Site 1 annual 10-m level wind rose showed the prevalent wind direction to be from the west-southwest, with secondary maxima from the south-southwest and from the southwest. The mean wind speeds associated with these directions were 8.9 mph, 9.4 mph and 6.6 mph, respectively. These data compare favorably with the previous two annual wind roses from the 10-m level at Site 1, which also show the prevalent wind direction to be from the west-southwest. During the current year, the Site 2 annual 10-m level wind rose showed the prevalent wind direction to be from the west, with secondary maxima from the southwest and from the west-southwest. The mean wind speeds associated with these directions were 9.5 mph, 12.2 mph, and 10.6 mph, respectively. These data compare favorably with the two annual wind roses from the baseline period at Site 2, which also show the prevalent wind direction to be from the west. During the current year the Site 3 annual 10-m level wind rose shows the prevalent wind direction, by far, to be from the west (35.8 percent of total annual occurrences), with secondary maxim from the west-southwest and the southwest. The mean wind speeds associated with these directions were 6.5 mph, 7.2 mph, and 10.8 mph, respectively. These data are similar to the two annual wind roses from Site 3 during the baseline period, which also show the prevalent wind direction to be from the west (36.1 and 28.5 percent of the total annual occurrences).

- Precipitation - The current year was the wettest of the three years at all three sites with an annual total precipitation of 9.57 to 11.37 inches measured at each gauge with a full record. During this year, the highest precipitation amounts were recorded during March and November, with the latter month including unusually heavy amounts of snow. The driest month was October.

- Solar Insolation - The annual mean solar insolation for each of the three data periods (two baseline years and current year) was 0.3 langleys/min, equivalent to 432 langleys/day.

- Visibility - Visual ranges obtained during Spring and Fall 1978 were generally high; 95 percent of the measurements were greater than 43 miles, 50 percent were greater than 71 miles. Daily mean visual ranges exhibited large variations during the periods, ranging from 29 to 102 miles; variations in mean hourly visual ranges were small, however, and were less than 15 miles in each view. The generalized visibility (mean visual range) was found to be 79 miles for the year. These data compare favorably with baseline values.

- Noise - Sound level averages taken during the January survey ranged from 45-66 dBA. These values reflected the spatial removal from site activities. Sound level averages taken during the March study were higher than during January, ranging from 82-110 dBA. However, these sites were in closer proximity to activity areas and were taken during periods of considerable activity. Sound level averages during August ranged from 61-76 dBA. The range in October was 61-78 dBA. These latter two values agree well with March data, which were taken at the same locations.

Terrestrial Studies

The terrestrial studies MDP monitoring program is designed to detect and evaluate those impacts affecting the soil, vegetation or faunal components of the terrestrial ecosystem on or near RBOSC Tract C-a. The terrestrial monitoring program is based on an assessment of current knowledge of MDP mining operations. Environmental parameters which are either expected to be affected by developmental activities or are ecologically or politically important have been included in the terrestrial monitoring program. Parameters included in the current program are listed on Table 6-2. The locations of the range and browse sampling sites are depicted on Figure 6-2. Mule deer and feral horse studies encompass the tract and a three-mile perimeter. Aerial photography studies encompass the tract and a five-mile perimeter.

Trace metal and soil conductivity studies will be initiated in 1979. A summary of results from other terrestrial programs follows.

- Vegetation Distribution (Mapping) - Aerial photography revealed small areas of disturbance in 1978 when compared to the baseline. No major changes in distribution of vegetation types or vegetation stress was noted, however.
- Range - Production of grasses and forbs in mixed brush communities totaled 185 lbs/acre in 1978. This compared to annual total production for these groups of 207 and 245 lbs/acre in 1975 and 1977, respectively. Production of grasses and forbs in the pinyon-juniper type totaled 38 lbs/acre in 1978 compared to 101 and 67 lbs/acre in 1975 and 1977. Total production for these plants in the upland sagebrush type was 110 lbs/acre in 1978, 269 lbs/acre in 1975 and 111 lbs/acre in 1977.

TABLE 6-2. TERRESTRIAL STUDIES MONITORING PARAMETERS AND PROGRAM SCHEDULE

Parameter	Location	Start Date	Frequency
Trace Metals (Collection & Storage of Soils and Vegetation Samples)	On Tract	Aug. 1981	Annually
Soil Conductivity Studies	On Tract	Aug. 1981	Annually
Vegetation Mapping	Tract C-a and 5 mile Perimeter	May 1978	Annually
Range Productivity and Utilization	See Figure 7-3-1	April 1978 (establish plots)	Annually (in Sept.)
Browse Condition and Utilization	See Figure 7-3-1	May 1978	Annually
Mule Deer Density Studies	Tract C-a and 3 mile Perimeter	Sept. 1977	Semi-annually (May, Sept.)
Feral Horse Abundance	Tract C-a and 3 mile Perimater	Jan. 1978	Annually
Threatened or Endangered Species	Tract C-a and Adjacent Areas	Sept. 1977	Opportunistically

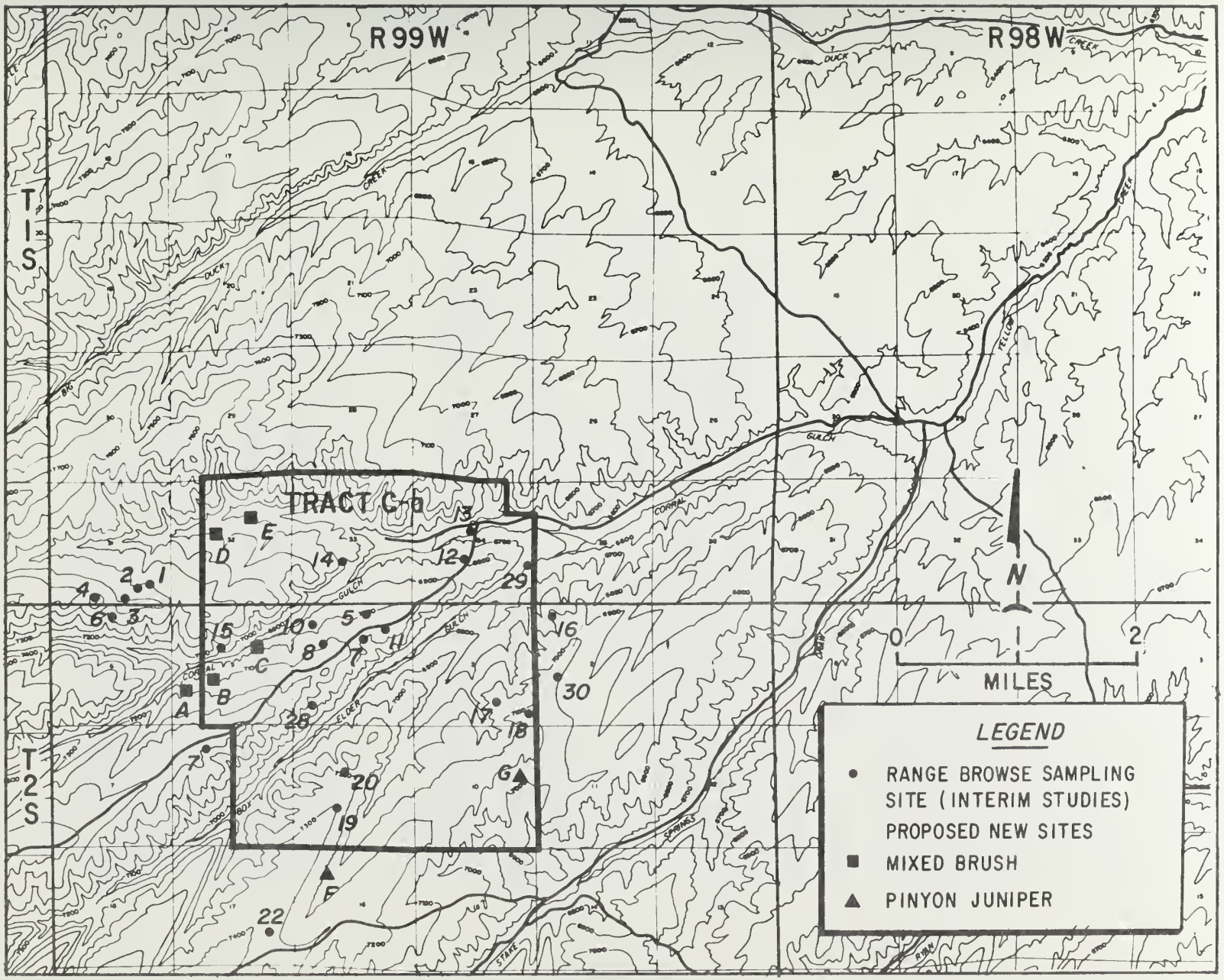


FIGURE 6-2. RANGE AND BROWSE SAMPLING SITES

In general, production substantially decreased from 1975 to 1977-1978; explanations for this decrease are not apparent. The 1977 and 1978 production levels were more similar although 1977 estimates were generally higher. The higher 1977 estimates are probably related to the late summer rains which occurred in late July and August of 1977 and could have affected the production measured in August. Precipitation during the 1978 growing season was concentrated in May and June; the effects of spring precipitation were probably negated by the time of the September sampling.

- Browse - A summary of the browse utilization results for Spring 1976, 1977 and 1978 is presented as follows:

Average Utilization (% Utilization)[1] in Three Vegetation Types During April 1976, May 1977 and May 1978 On and Near Tract C-a

	April 1976	May 1977	May 1978
Mixed Brush	12	17	7
Pinyon-Juniper	27	24	31
Upland Sagebrush		6	25

[1]The comparison is for the habitat type in general; the same transects were not sampled during each period nor was the sample size equal.

During the first year of MDP operations (1978), pinyon-juniper and sagebrush had the highest utilization while utilization in mixed brush decreased from 1976 and 1977. Utilization in the sagebrush type was substantially higher than the utilization measured during 1977. A comparison of the individual transects (RBOSC 1978b) indicated that the increase in utilization was probably related to feral horse use. Therefore, it is doubtful that MDP activities affected utilization in the sagebrush area.

- Mule Deer - The estimated average number of mule deer per square mile in the study area during the winter period, 1977-78, ranged from 9.0 to 100.0. The average number per square mile during the summer period ranged from 4.7 to 28.5. The average winter use by square mile for the entire study area was 50.9; in summer 15.3. RBOSC data agree well with Colorado Division of Wildlife data.

  Number of deer killed on the 13 mile stretch of County Road 24 leading into the tract has been low. Daily counts tallied less than five dead animals along this route from February through December 1978.

- Feral Horses - The January 1978 feral horse survey revealed the presence of seven bands of horses totaling 53 individuals in the area is from 80-100 individuals. Horses were observed regularly throughout the area, many in close proximity to activity sites.

- Threatened or Endangered Species _ Tract C-a does not provide critical habitat for any state or federally endangered species. Bald eagles are occasionally seen during the winter months, and may utilize road-killed animals as a source of food.

Aquatic Studies

The aquatic studies MDP monitoring program is designed to identify changes in the aquatic ecosystem which result from tract development, to provide continuing information on natural variation and ecosystem characteristics, and to provide a means for mitigating adverse impact, should they occur. The current program was designed in view of baseline data and an impact assessment of potential development effects. The six

sampling sites currently being monitored are depicted on Figure 6-3. Both abiotic and biotic parameters are being monitored. A list of these parameters, the locations at which the data are collected and the data collection schedule are identified on Table 6-3. A summary of the current year's data and results of these comparisons follows:

- Physical Measurements - Physical parameters (width, depth, velocity) at Stations 13 and 14 on Corral Gulch were affected by increased flows of dewatering discharge during the reporting period. Other physical parameters were not significantly affected,at the two Yellow Creek stations by the 1977 drought conditions. No change was observed in physical parameters measured in the White River.

- Water Quality - Water quality is measured as a part of the aquatic program at only two stations at the White River. More extensive water quality data are presented in Section 5 - Hydrology. Water quality at the two White River stations doesn't vary substantially from baseline conditions.

- Periphyton - Total cell densities for periphyton were generally lower at most stations during the current year than during baseline. This lower cell count was reflected in lower diversity indices. This trend was especially noted at Stations 13 and 14 which also underwent a considerable change in habitat characteristics, as noted earlier. Variations were noted between seasons of the years as well as by station. These changes may reflect some natural variation as well as effects of development activities.

  At certain times of the year total mean cell densities were greater than values recorded during baseline. This was noted in April and July at Station 20 on Yellow Creek. However, densities noted in October at this station were substantially

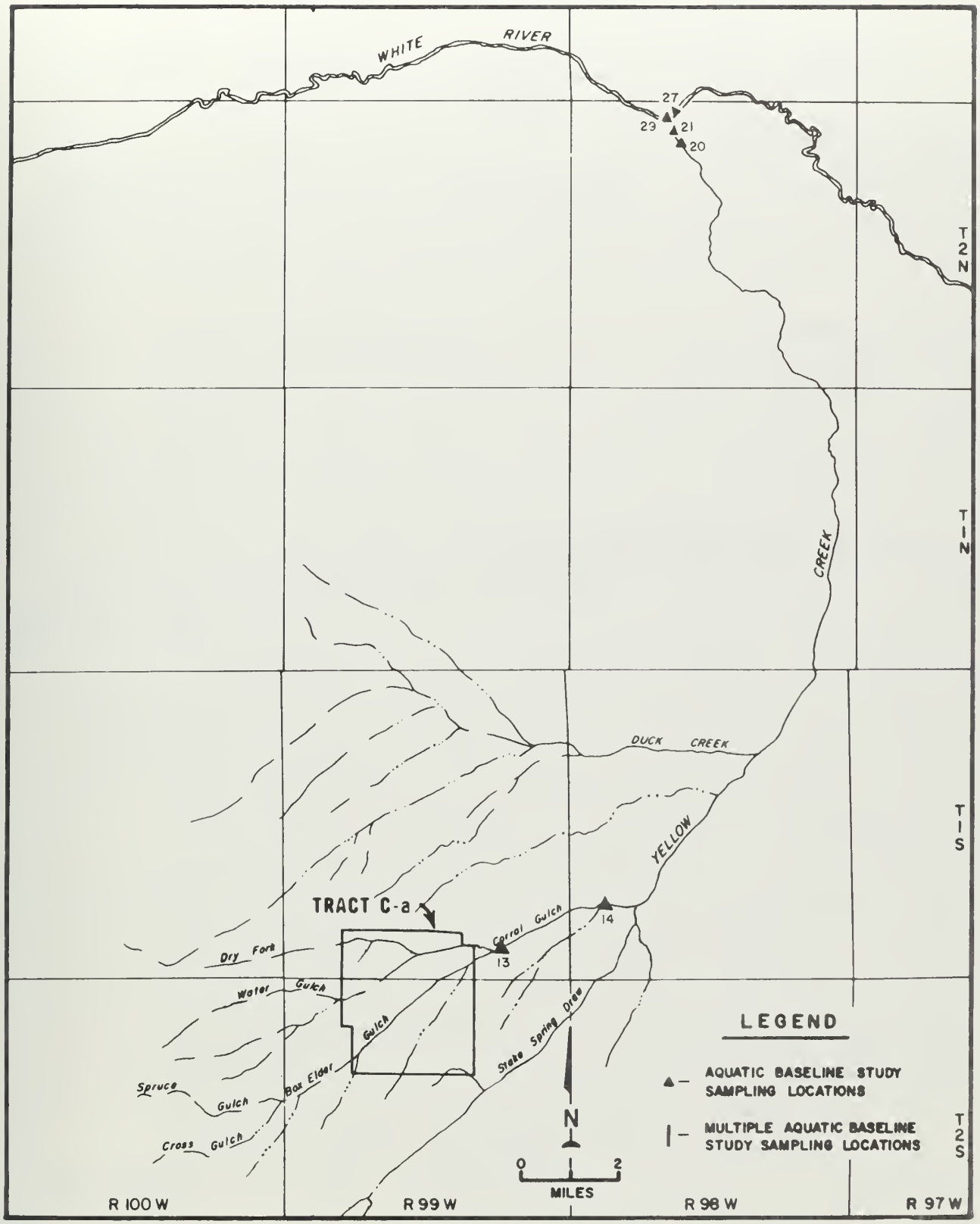


Figure 6-3 Locations of Aquatic Ecology MDP Sampling Sites

TABLE 6-3. AQUATIC STUDIES MONITORING PARAMETERS AND PROGRAM SCHEDULE

Parameter	Location	Start Date	Frequency
	ABIOTIC		
Physical Measurements			
Stream Velocity Turbidity Dissolved Oxygen pH Specific Conductance Water Temperature Depth Width Stream Substrate	Stations 13, 14 20, 21, 27, 29	Oct. 1977	5 times/year (April, June, July, Aug., Oct.)
Water Quality Measurements (White River)			
Boron Calcium Chloride Fluoride Magnesium Nitrate Orthophosphate Potassium Total Phosphate Silica Sulfate Sodium Alkalinity Total dissolved solids	Stations 27, 29	Oct. 1977	5 times/year (April, June, July, Aug., Oct.)
	BIOTIC		
Periphyton	Stations 13, 14 20, 21, 27, 29	Oct. 1977	5 times/year (April, June, July, Aug., Oct.)
Benthos	Stations 13, 14 20, 21, 27, 29		5 times/year (April, June, July, Aug., Oct.)

lower. Densities at stations on the White River were almost exclusively lower. Natural flood conditions may have been responsible for this trend. Trends noted during the current year reflect changes, but do not necessarily indicate adverse impact, as demonstrated by the continued diversity of the communities despite scouring from high flows, and changes in total cell densities and organic weights. The communities identified during the current year are indictive of oxygenated, highly alkaline waters such as were present during the baseline period.

- Benthic Macroinvertebrates - Changes were noted in macroinvertebrate populations at Stations 13 and 14 during the reporting period. The previously well-balanced and diversified benthic community at Station 13 was altered by the disappearance or reduction in numbers of several benthic groups, including Baetidae, Plecoptera, Naididae, and Chironomidae. Station 14 showed trends toward a depositional habitat with an increase in numbers of Tubificidae and a decrease in Chironomidae larve. As discussed earlier, the physical characteristics of both stations were affected by dewatering discharge. Additionally Station 14 has undergone several habitat conversions over the last four years. These habitat alterations from pond to flood stream to study. The composite of the four views is also illustrated in Figure 2-27. On an "average" day, the mean hourly visual range pond again have resulted in considerable variation in the benthic community at this station. These alterations have also demonstrated the adaptability of the benthic community to drastic alterations in habitat. Therefore, while changes in the habitat have affected the biotic component, these changes are not unique to oil shale development. They have resulted from natural flooding and runoff as well as from dewatering discharge. Short-term changes such as those noted to date cannot be assessed as adverse.

Benthic populations at Station 20 on Yellow Creek remained stable during the study period and compared favorably with baseline. Small changes in the benthic community were noted at the other Yellow Creek Station (21), but no definite trends were noted.

The two White River Stations (27 and 29) continued to support the most diverse, stable, and well balanced benthic community of all the study sites, as established during baseline.

Hydrology

The Tract C-a hydrology program is comprised of two distinct elements - environmental and operational hydrologic studies. The environmental hydrology program provides data necessary to: satisfy lease stipulations and conditions of approval from the AOSS; assess impacts of ongoing development activities; provide input for other environmental disciplines; and to supply information necessary to institute mitigative measures, if necessary. The operational hydrology program is carried out to: provide engineering input to mine design and dewatering; collect data for compliance with permit stipulations; and to describe the effects of dewatering and reinjection.

The environmental hydrology program supplements baseline data and is used as a means of providing current data for comparison purposes. This program was initiated in September 1977. The major elements of the environmental program are identified on Table 6-4. The locations of the six springs currently being monitored are shown in Figure 6-4. The locations of other hydrologic monitoring sites identified in Table 6-4 are depicted in Figure 6-5.

TABLE 6-4. ENVIRONMENTAL HYDROLOGY MONITORING PARAMETERS AND PROGRAM SCHEDULE

	Frequency		
	Continuously	Quarterly	Semi-Annually
SURFACE WATER PROGRAM			
Stream Gaging Stations			
DOC Fractionation (once initially)			
Conductivity	x(6)		
Temperature	x(6)		
Flow	x(6)		
Limited water quality analysis		x(6)	
Complete water quality analysis			x(6)
Springs and Seeps			
DOC Fractionation (once initially)			
Flow		x(6)	
Conductivity		x(6)	
Temperature		x(6)	
pH		x(6)	
DOC		x(6)	
Surface Water Impoundments (which contain water)			
Complete water quality analysis			x
Limited water quality analysis		x	
GROUNDWATER			
Alluvial Holes			
DOC Fractionation (once initially at new holes)			
Water levels	x(3)	x(5)	
Limited water quality analysis		x(8)	
Baseline water quality analysis			x(8)
Dual Aquifer Monitor Holes			
Water levels	x(6)		
Complete water quality analysis			

(6) Indicates the number of sampling sites

The data collected as a part of the operational monitoring program are identified on Table 6-5. The locations of the sampling locations are shown on Figure 6-6. The results of these two programs are briefly summarized below.

- Surface Water - Of the six gaging stations, only one, Rinky Dink Gulch, failed to show any flow during the reporting period. The natural flows for 1978 were similar to earlier data. Box Elder Gulch flowed with more frequency than in 1977, but Corral Gulch and Yellow Creek flow records were quite similar to baseline data. Flows recorded in 1977 definitely exhibit effects of the drought at all stations except Dry Fork, which did not register a flow reduction. Examination of the physical data collected at surface gaging stations during 1978 indicates that concentrations of most constituents varied outside expected statistics. Correlations noted between various constituents during baseline were in some cases no longer detected.

- Springs and Seeps - Physical data recorded at springs and seeps during the reporting period were similar to baseline values.

- Alluvial Groundwater - Most of the alluvial wells in the study area remained dry throughout the reporting period. This approximates the baseline condition. For the remaining wells where data were collected, the following can be noted. Physical data for two of the alluvial wells (G-S S-7 and G-S S-8) showed no significant difference from baseline values. Water level in G-S S-27 appears to have been influenced by mine water discharge.

  Statistical analyses were performed to determine if changes in water level increases could be related to water quality.

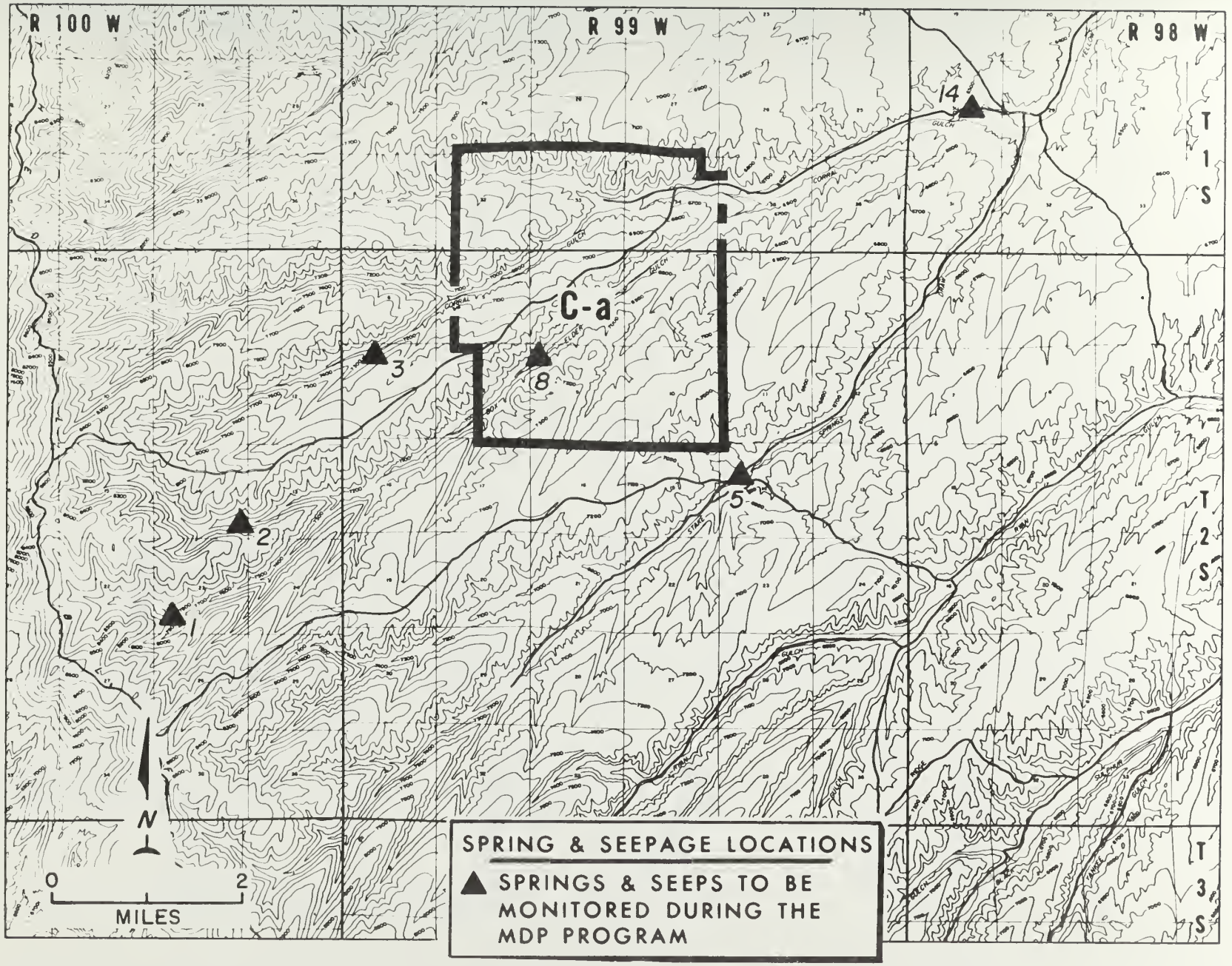


FIGURE 6-4. LOCATIONS OF SPRINGS AND SEEPS MONITORED AS A PART OF THE MDP ENVIRONMENTAL HYDROLOGY PROGRAM

TABLE 6-5. COMPONENTS OF THE OPERATIONAL HYDROLOGY MONITORING PROGRAM

Requirement	Parameters	Locations
CDOH Subsurface Disposal Permit	Flow/water level, Limited water quality analysis, Physical characteristics, Semi-annual complete water quality analysis.	Gaging stations, Reinjection points, Alluvial holes, Upper aquifer holes
NPDES Permit	Flow, pH, Conductivity, TSS, TDS, Oil and grease, Fluoride, Boron	Discharge points
MDP pump test Monitoring	Flow/water level, Conductivity, pH, Temperature	Gaging stations, Upper aquifer holes, Alluvial holes
	Channel cross-section	Streams
	Limited Water quality analysis	Impoundments
	Water level	Lower aquifer holes

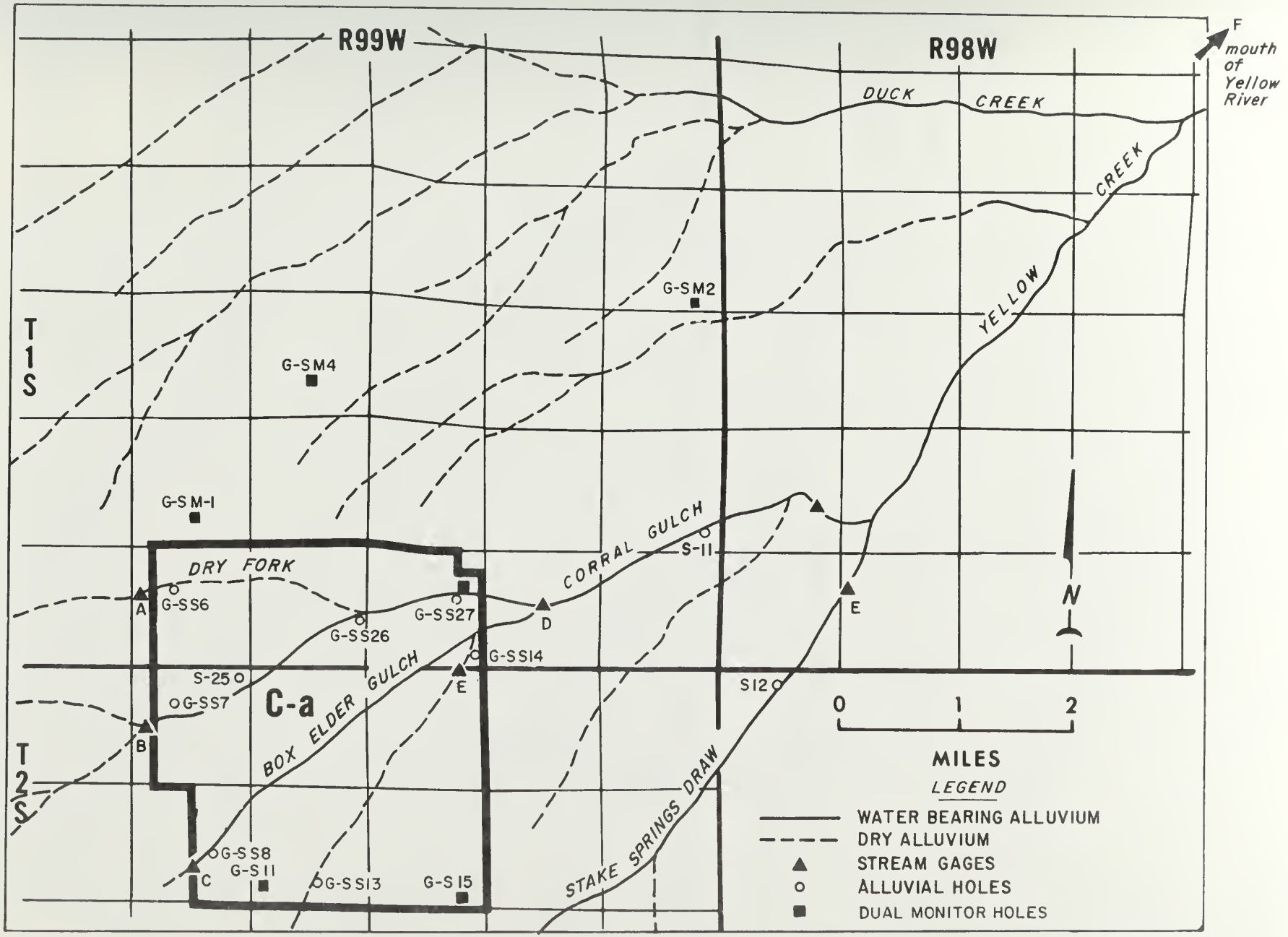


Figure 6-5. Locations of Monitoring Stations for Hydrology Studies During the MDP.

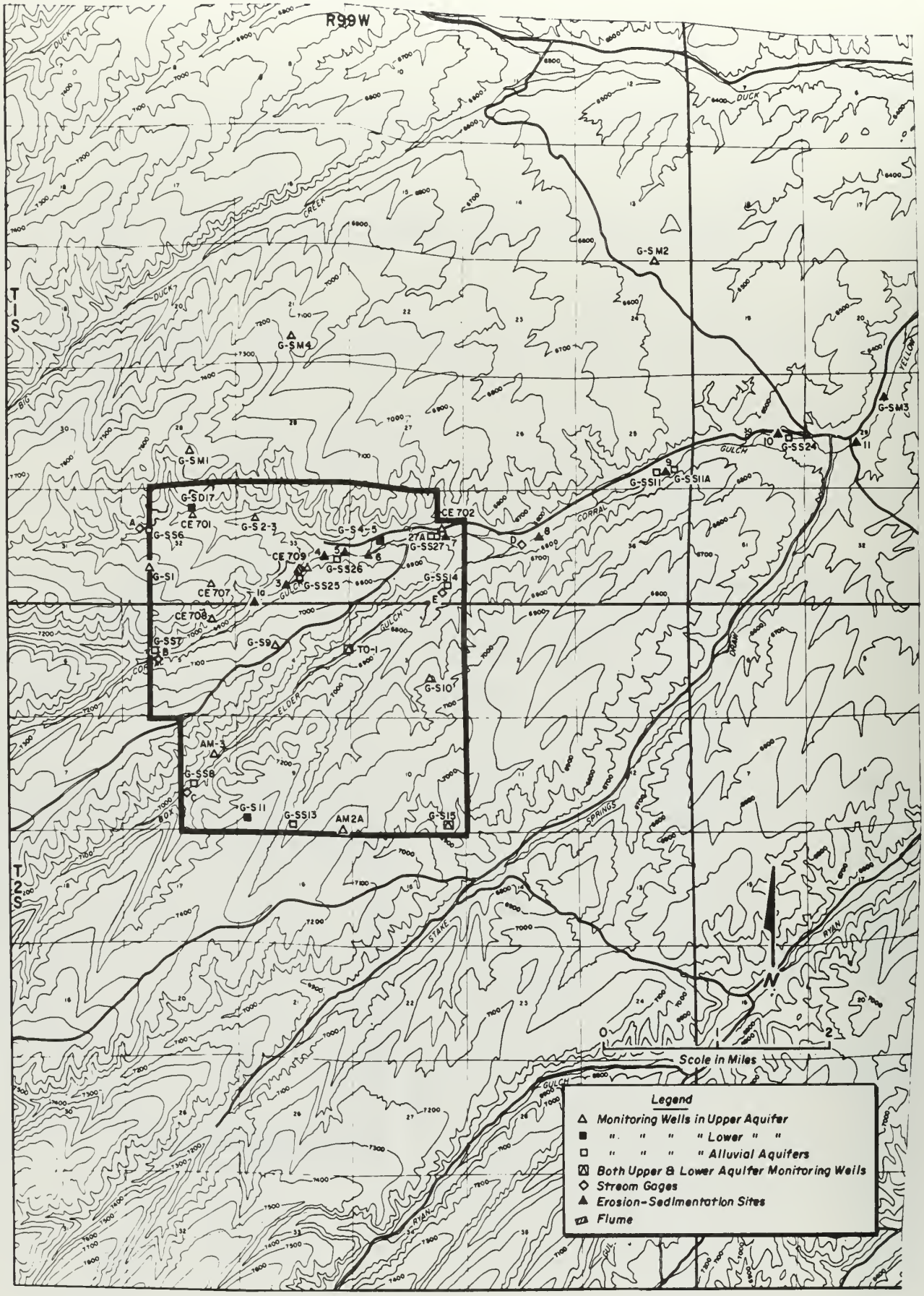


FIGURE 6-6 Locations of Operational Monitoring Hydrology Sampling Sites.

- Upper and Lower Aquifer Water - Water levels in two of the deep oil shale aquifer wells showed definite changes in 1978. These changes appear to be related to dewatering and reinjection activities. These water levels are being watched carefully to determine the effects of the dewatering program on the upper aquifer in the area. Other wells in the monitoring program show no affects.

  Chemical data for deep aquifers taken during 1978 compared favorably with baseline. Only a few variations from accepted statistics were noted. These changes were related to factors other than tract development. Therefore, water quality has apparently not been affected by tract development to date.

- Operational Monitoring - Flow data taken during the reporting period reflect discharges to Corral Gulch during the pump testing program. Likewise erosion data indicate that initial discharges to Corral Gulch resulted in changes in the stream channel profiles. However, these changes leveled off after the initial disturbance and have remained relatively stable since.

  Subsurface disposal permit data have been reported monthly since the onset of the testing program. These reports are available through the Colorado Department of Health.

R100W

R99W

R98W

T1S

T2S

Met. Site 1

Met. Site 2

Met. Site 3

0 1 2

Scale in Miles

Legend

- *Industrial Disturbance*
- *Surface Disturbance*
- *Revegetation*
- *Clear Cut*

Figure: 3.1

AREAS OF DISTURBANCE ON AND AROUND TRACT C-a
AS OF NOVEMBER 1978

9
4
6700
6700
6600
6700
6800
6700
33
6900
7000
6800
7000
6900
10

Form 1279--3
(June 1984)

BORROWER'S C

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